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ALTERNATIVE ACQUISITION STRATEGIES FR TRAINING SYSTEMS
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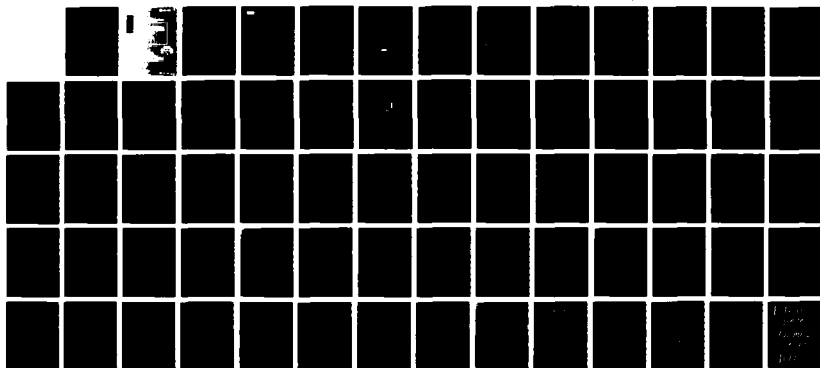
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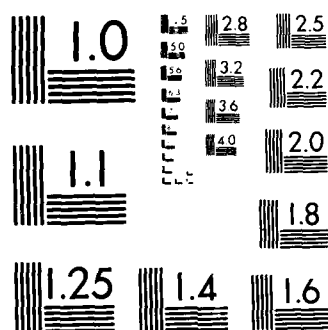
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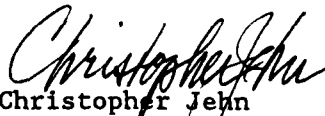
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1. This Research Memorandum represents the final documentation of a CNA project requested by the Deputy Chief of Naval Operations (Surface Warfare). It assesses the government procurement process for training devices and focuses upon methods of reducing the length of the procurement process. Alternative acquisition strategies are analyzed and the strengths and weaknesses of each approach are described. The analysis is supported by evidence from current Navy and Air Force programs. Prospective procurements are discussed in light of the conclusion of the analysis.

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ALTERNATIVE ACQUISITION STRATEGIES FOR TRAINING SYSTEMS

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ABSTRACT

The Navy may take between six to seven years to procure a training device. This research memorandum describes and evaluates alternative acquisition strategies currently used by the Navy, with the objective of identifying methods of shortening the procurement process. Conclusions are drawn regarding the merits and drawbacks of each approach.



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INTRODUCTION

The Navy continues to be concerned with both the length of the government procurement process for training devices and the cost of obtaining training equipment. Traditionally, the Navy Training Systems Center (NTSC) plays the central role in procuring training devices for the surface Navy. Under NTSC procedures, six to seven years may elapse between the identification of a new requirement and the completion of a training facility. Alternative methods of acquiring training devices and/or training systems may reduce both the cost of the system and the time necessary to field the system. This report examines and evaluates alternative acquisition strategies the Navy currently uses to a limited extent. Comparing these less frequently used options with the typical method of procuring training systems reveals the merits and drawbacks of each approach.

The report begins with a brief description of the alternative acquisition strategies. The alternatives include:

- Leasing training equipment
- Bundling training devices and support
- Purchasing training services.

A review of the NTSC procurement process for obtaining training devices suggests that devices might be acquired more quickly and at lower cost under the alternative strategies. This paper then describes the statutory and regulatory requirements that pertain to trainer acquisition. It goes on to consider the effect of each strategy on the scheduling of students for training, the quality of instruction, the budgeting process, manpower requirements, and sea/shore rotation ratios as well as cost and time lines. The section following thereafter describes several current programs in which the Government is pursuing a training-services approach. These examples offer guidance to the implementation of future training acquisitions. The report concludes with a discussion of the applicability of the procurement initiatives to current Navy training programs.

A lack of quantifiable data constrained this study. As a result, discussion with project managers at NTSC, Navy and Air Force representatives, contractors, and contract specialists in the Government provided the observations and insights used to evaluate the alternatives. A review of statutory requirements as well as Department of Defense and Department of the Navy regulations, which restrict the implementation of each alternative, reinforced these discussions.

ALTERNATIVE ACQUISITION STRATEGIES

Several alternative methods for obtaining training equipment and/or establishing training systems offer the potential for quicker, less costly acquisition. Typically, the Navy obtains training systems in a somewhat fragmented manner. The NTSC assumes the main responsibility for training-device acquisition. However, training devices are only one part of the overall training system. The Navy must also provide facilities, instructors, and curricula, as well as maintenance, support, and modification of the training equipment.

The Navy relies on contractors for many of these separate functions. For example, the Navy recently switched to contractor maintenance of simulators under the Contractor Operation and Maintenance of Simulators (COMS) program. However, in cases where the Navy assigns different contractors to different tasks, determining accountability for the operation of the training system becomes difficult. The difference between the current system and the alternatives under study lies not in the use of the contractors but in tying together some of the separate functions and assigning them to a single contractor.

The alternatives considered here are:

- Leasing training equipment
- Bundling training devices and support
- Buying training services.

These alternatives, with some variations, represent the different types of acquisition strategies being developed by the Navy and the Air Force. The options differ according to the role they assign to the contractor in developing a training system. Under the leasing option, the contractor provides only the training devices. At the other end of the spectrum, the training-services option, the contractor provides a comprehensive training system. This option seems to be a promising acquisition method for training.

Under the leasing option, the Navy obtains training devices and maintenance in a leasing agreement. The Navy separately procures or provides other training system components. This option receives little consideration in this study but provides a useful point of reference in the comparison of alternatives.

The bundled purchase of training devices and support resembles leasing in that the contractor provides maintenance and support along with the training devices. However, in the bundled-purchase option, the Navy initially purchases the equipment and subsequently pays the contractor for maintenance support. The maintenance contract ties payments to equipment availability rates and assesses penalties for

failure to achieve the specified rate. NTSC recently proposed this acquisition strategy for Device 20A66, a surface tactical team trainer. Under this proposal, the contractor would be liable for maintaining the equipment at a 95-percent availability rate.

Under the training-services option, the Navy purchases training rather than training equipment. The Navy specifies the performance level to be achieved by the student rather than the type of equipment to be used in conducting training. This allows the Navy to minimize its role in the development of the training system. The contractor builds a facility, obtains the training devices, hires instructors, and develops the curricula. The Navy sends students to the training facility and specifies the criteria by which the training is evaluated. The Navy recently met the need for ship-handling training at the Surface Warfare Officers School by adopting this strategy.

Together, these three strategies and the typical procurement process provide a continuum of alternative acquisition strategies that vary in the roles assigned to a (single) contractor. Table 1 exhibits the different levels of responsibility taken on by a single contractor under the different acquisition strategies. The Navy can then choose the most appropriate method for a given procurement.

THE NTSC PROCUREMENT PROCESS

A detailed description of the NTSC procurement process helps explain why the process is so lengthy and identifies the steps determining the time lines. A discussion of this topic is included in this section. Appendix A provides more detailed information.

NTSC involvement in the acquisition of a surface warfare training device begins with an operational requirement from the sponsor, OP-03. Training systems and devices fall into either the weapon-system-specific category or the generic category. Weapon-system-specific trainers teach operational and maintenance skills for weapon systems. Generic trainers teach skills such as tactical decision making or fire fighting.

Within the surface warfare area, the Navy procures generic trainers through NTSC. The Navy procures weapon-system-specific training equipment through two independent paths. The traditional procedure assigns the major role to NTSC, which conducts the initial analysis, issues the requests for proposals, awards the contract, and oversees the activities of the contractor following source selection. For weapon-system-specific trainers, the program manager for the weapon system may choose to develop the training system through the prime contractor. (The prime contractor may subcontract this work to others.) Recently, more program managers have chosen this path, which may be quicker and cheaper.

TABLE 1

ROLE OF SINGLE CONTRACTOR

<u>Buying equipment</u>	<u>Leasing equipment</u>	<u>Training services</u>
Manufacture equipment	Manufacture equipment	Manufacture equipment
	Maintain equipment	Maintain equipment
		Develop curriculum
		Hire instructors
		Construct building

Once assigned the task of procuring a training device, NTSC organizes a project team to oversee the design, development, and acquisition of the training device. A project manager from the Program Management Department heads the team, which also includes representatives from the Training Analysis and Evaluation Department, the Engineering Department, the Fleet Support and Field Engineering Department, and the Contracts Department. The teams remain together for an average of seven to ten years. Table 2 summarizes the major responsibilities of the representatives of these departments.

This NTSC acquisition process consists of four components:

- Analysis
- Development
- Support
- Funding.

The analysis phase precedes development, which, in turn, precedes support, although support planning will begin much earlier in the process. Funding needs to be planned as early as possible to ensure that dollars are available as and when they are needed.

TABLE 2

ACQUISITION PROJECT TEAM MEMBERS

Team member	Responsibilities
Project Manager	Directs activities of acquisition team. Coordinates development of equipment facility requirements plans, integrated logistics support (ILS) plans, and acquisition plans. Conducts military characteristics and specification reviews. Coordinates with sponsor on acquisition and budgetary goals and authority.
Analysis Manager	Oversees front-end analysis. Identifies training deficiencies and alternative solutions. Develops military characteristics. Provides data for Program Objective Memorandum (POM) and Navy Training Plan.
Project Engineer	In the contract definition phase, finalizes precontract award design studies, development of specifications, procurement documentation, and technical evaluations of prospective contractor proposals. In the acquisition phase, responsible for training system design, progress reviews, and technical acceptance. In the operational phase, technical manager for life-cycle modification/modernization changes.
ILS Manager	Oversees development of the ILS plan for the project to ensure effective and economical support of the device.
Contracts Specialist	Prepares invitations for bids and requests for proposals. Selects negotiation authority, where appropriate, and type of contract and determines evaluation factors. Solicits and analyzes bids and proposals. Makes preaward investigations. For negotiated contracts, conducts negotiations and selects offeror.

Analysis

During the analysis phase, the project team assesses the training requirement, identifying training deficiencies and alternative solutions and defining the physical and functional requirements of the device or system chosen as the best approach.

NTSC and the remainder of the Navy interact a great deal throughout the acquisition process. In particular, a Fleet Project Team (FPT) of 20 to 30 Navy representatives from operational commands provide advice and review throughout the development of the training system. The military characteristics (MC) document, which concludes the analysis component, defines the basic physical and functional baseline training requirements of a device. The FPT, relevant systems command, and the cognizant CNO warfare sponsor review and approve the MC document, which defines the device to be acquired by NTSC on behalf of the sponsor. Indeed, it is referred to as a "contract" between the sponsor and NTSC.

Development

The development component of the acquisition process includes the development of the acquisition package, the solicitation of proposals, the evaluation of proposals, the selection of the contractor(s), and the project performance by the contractor(s). This component is divided into three phases, request for proposal (RFP), source selection, and contractor design and development.

During RFP generation, the NTSC project team assembles an acquisition package containing all of the data necessary to go to contract. The package defines the requirement and contains the authorization to fund the requirement. The project manager concurrently develops an acquisition plan, which describes the contracting activities proposed for the project, and a proposal evaluation plan, which describes the methods to be used for evaluating contractor proposals. Both must be submitted for approval by the Assistant Secretary of the Navy for Shipbuilding and Logistics (ASN, S&L). Routine approval normally takes three to nine months. A sole-source justification typically takes from three months to a year.

During the source-selection stage, the project team issues the RFP, evaluates the proposals submitted by contractors, and makes a contract award. The size of the proposals affects the length of the evaluation period. For example, a 2,000-page proposal may require six weeks to read. In addition, the RFP must be synchronized with the budgetary process to ensure that funding authorization coincides with contract award. During contract negotiation, the contracting specialist negotiates with the selected contractor. The ASN, S&L, must approve a prenegotiation memorandum describing the Government's negotiating position. This normally requires two to three months. Source selection routinely requires 15 months.

During the design and development stage, the selected contractor must perform the required project tasks. The NTSC project manager oversees the work of the contractor to ensure compliance with the contract. This normally involves numerous conferences, reviews, and inspections at which the contractor demonstrates progress in the development of the training device. Separate reviews may be necessary for the hardware, software, and support project parts.

Support

The support component of the NTSC acquisition process entails the transition from full-scale development to production, deployment, and support of the training system. Support continues for the life cycle of the device/system. However, the support process begins early in the development of the training system. During the analysis phase, the ILS manager, a member of the project team, begins to develop an ILS program for the project. The ILS manager assembles an ILS management team that establishes, updates, and evaluates the ILS portions of the project. Preparation of an ILS plan begins immediately after project initiation with a draft ILS plan.

During the development phase, the ILS management team reviews the ILS specification in the acquisition package and the RFP. After contract award, the ILS manager holds a series of conferences to review, update, and approve the contractor's ILS plan. The original manufacturer of the training equipment provides logistic support during the initial support period, typically one year after installation of the equipment. At the end of this period, the successful bidder under the COMS program assumes responsibility for support of the training device.

Funding

Once analysis establishes the need for a training device, funds must be obtained for the acquisition. Some governmental unit, along with the NTSC project manager, must estimate how much the required device/system will cost (presumably based upon the typical procurement process). That governmental unit must then convince the Congress to appropriate the needed funds. A major command is designated to allocate those funds for the procurement. Those funds must then go through the proper procurement channels to allow the project manager to commit, obligate, or expend the funds for the device or system that meets the requirements. Because of the number of organizations involved in budgeting and the numerous iterations of the process, funding should be planned as far ahead as possible. Indeed, the budgeting process must begin about three years before the anticipated contract award. This constraint means that the funding process must begin as soon as the analysis phase establishes the requirement.

Direct involvement by NTSC personnel in the planning, programming, and budgeting system (PPBS) cycle occurs primarily in the programming

phase, when sponsors must identify the authority necessary to procure the training system. The project manager must submit data for inclusion in the POM process, including a POM justification data sheet, a cost-element breakdown sheet, and a funding profile. The POM justification data sheet lists the device, number of units, location, and costs, as well as related information on spares, Government-furnished equipment (GFE), and military construction (MILCON) requirements. The POM justification data sheet also describes the item and its purpose and identifies the sponsor. The cost-element breakdown sheet contains additional information on the device. The funding profile describes all types of funding associated with the training device procurement.

The project manager assigns various tasks to project team members to develop the POM submittal. The analysis manager determines the latest requirements, the number of devices, and when and where the devices are required. The project engineer generates development schedules, cost estimates, and MILCON and GFE requirements with the assistance of the ILS manager.

The Length of the Procurement Process

Interviews with representatives of NTSC provided some insight into the factors contributing to the length of the procurement process. These representatives cited as problem areas the difficulties in defining requirements, budgeting uncertainties, and production delays.

During the analysis component, the development of the MC document may require anywhere from four months to four years. The length of the effort varies with the complexity, controversy, and realism required of the training equipment. Differences in operational practices in the fleets make it difficult for the FPT to agree on the requirements of the system. In addition, FPT members fail to make tradeoffs between cost and performance, typically opting for the "gold-plated cadillac."

The acquisition process must be synchronized with the budgeting process. Approval of the military requirements must be matched with approval of funds. The RFP must be issued no more than a year before the dollars are appropriated. In addition, any delays in the approval process slow the procurement process.

Once NTSC issues the RFP and receives proposals, the proposal-evaluation process begins. Proposals arrive in five volumes: technical, ILS, systems engineering, administrative, and cost. The increasing length of both RFP and proposal sizes contributes to the length of the development phase. NTSC representatives argue that lengthy RFPs result from the detailed specifications necessary to ensure that the Government receives the desired training equipment. According to [7], if the RFP does not definitely stipulate what product is expected of the contractor, the Government may not receive what is required. The need to specify requirements with precision undoubtedly contributes to the

length of RFPs. However, this does not mean that all of the information requested in an RFP is critical.

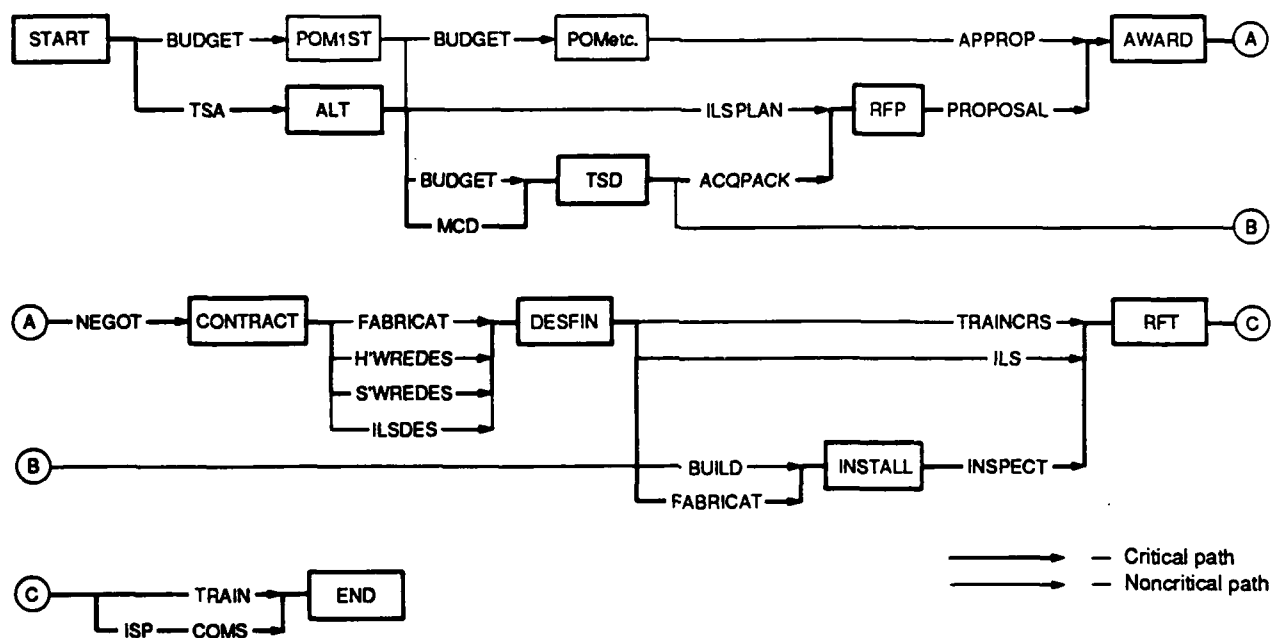
After contract award, the NTSC project manager must organize a series of design reviews and ILS management conferences to oversee the contractor's performance. Changes in the nature of the training due to the changes in operational equipment or tactics require the modification of the training equipment during its development. In addition, despite the fact that training equipment is used in controlled environments, the same Navy standards used in developing weapon systems and ships apply to training devices. Data requirements relating the operation, maintenance and support of the device add considerably to both the cost and time necessary to reach ready-for-training (RFT) status.

NTSC representatives directed most of their comments about the length of the procurement process to the analysis and funding components. If, as NTSC representatives suggest, difficulties defining requirements and obtaining funds are the major sources of delay, then the effect of the alternative strategies may not be large. However, evidence on the sources of time savings, obtained from studying examples of the training-services option, suggests that the "alternative strategies" allow significant time savings, especially the areas of development and support.

It is useful to have a visual representation of the various tasks that make up the training system acquisition process, including their timing and interrelationships. Because of variations between different procurements, no figure uniquely represents the trainer-acquisition process. Instead, figures 1 and 2 describe a representative procurement. Figure 1 is a program evaluation and review technique (PERT) chart that describes the major tasks, milestones, and workflow. Figure 2 is a schedule corresponding to the PERT chart.

An examination of figures 1 and 2 indicates areas in which efficiencies may decrease the length of the acquisition process. For example, the preparation of a military characteristics document (MCD) is on the critical path. Thus, a reduction in the time to produce an MCD should lead to a swifter acquisition process. The time necessary to complete parallel tasks, such as funding, limits such time savings. Conversely, the development of the training course (TRAINCRS) is not on the critical path. So, there would be no time savings accruing from a reduction in the time taken to develop the training course.

Figures 1 and 2 represent the main points of a training-system acquisition process. However, individual training systems will show marked differences in the complexity and timeliness of their corresponding task schedules, preventing precise conclusions from being drawn from these figures.



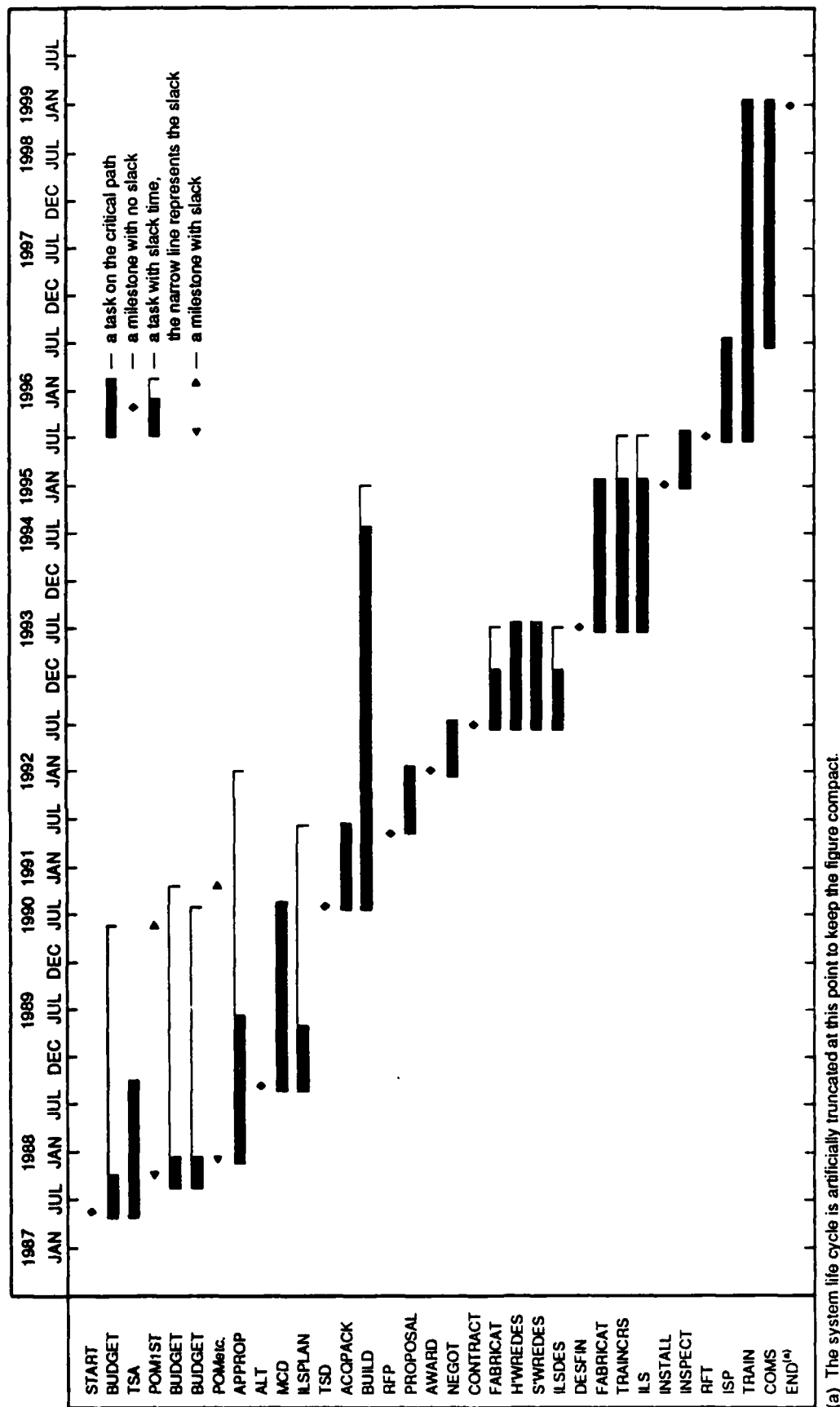
Tasks

- TSA — Conduct training situation analysis (i.e., requirements definition)
- BUDGET — Prepare budgetary information
- MCD — Develop military characteristics document (i.e., specifications)
- ACQPACK — Develop acquisition package
- ILSPAN — Develop ILS requirements for inclusion in RFP
- PROPOSAL — Proposals are developed, submitted, and evaluated
- APPROP — Obtain appropriation for trainer
- NEGOT — Government negotiates with selected contractor
- FABRICAT — Fabricate the training device
- H'WREDES — Design the hardware
- S'WREDES — Design the software
- ILSDDES — Prepare ILS plans
- BUILD — Construct any necessary buildings
- TRAINCRS — Develop required training course
- ILS — Develop and prepare ILS materials
- INSPECT — Inspect the installed trainer
- ISP — Interim support period by development contract
- COMS — Contractor operation and maintenance support
- TRAIN — Utilize simulator in training Navy personnel

Milestones

- START — Initiate trainer system acquisition process
- ALT — Select one of several alternative trainers for further development
- POM1ST — Initial POM submission
- POMetc. — Subsequent POM and other budgetary submissions
- TSD — Complete training system specification
- RFP — Issue requests for proposals
- AWARD — Select contractor for award
- CONTRACT — Sign contract with successful bidder
- DESFIN — Completion of training system design
- INSTALL — Install trainer
- RFT — Obtain state of "ready for training"
- END — Completion of trainer life cycle

FIG. 1: PERT CHART OF REPRESENTATIVE ACQUISITION PROCESS



(a) The system life cycle is artificially truncated at this point to keep the figure compact.

FIG. 2: SCHEDULE OF REPRESENTATIVE TRAINER ACQUISITION PROCESS

STATUTORY AND REGULATORY REQUIREMENTS

Various statutory, Department of Defense, and Department of the Navy regulations limit the implementation of these alternative acquisition strategies.

Regulations Affecting Leasing

Leasing, and, in particular, leasing as a means of acquiring ships, aircraft, and other equipment, receives close scrutiny by Congress, which perceives it as an attempt to bypass congressional oversight. Regulations concerned with leasing seek to ensure that long-term leases provide a cost-effective means of acquisition. In general, these regulations discourage leasing if it is more costly than the purchase option.

The Federal Acquisition Regulations (FARs) establish uniform procurement policies and procedures for all executive agencies [1]. The Department of Defense Supplement to the FAR offers additional guidance for all Department of Defense components. Subpart 7.4 of the FAR deals with the decision to lease or purchase. Subsection 7.401, Acquisition Considerations, requires a case-by-case analysis of comparative costs and other factors to determine whether to lease or buy. The factors to be considered in the analysis include:

- Estimated length of purchase
- Financial and operating advantages of alternative types of equipment
- Cumulative rental payments for estimated period of use
- Net purchase price
- Transport and installations costs
- Maintenance and other service costs
- Potential obsolescence due to imminent technological change.

Subsection 7.402, Acquisition Methods, states that the purchase method is appropriate if equipment will be used beyond the point in time when cumulative leasing costs exceed purchase costs. The statement does not specify the use of discounted costs. However, it is a standard Government practice to discount leasing costs to a net present value during the evaluation of hardware-procurement proposals. Use of the lease method must be to the Government's advantage. However, leasing can be used if circumstances require the immediate use of equipment to meet program goals but do not support acquisition by purchase. If a

lease is justified, a lease with option to purchase is preferable. FARs (Section 17.204) dictate that the lease run for no more than five years, including option years, unless otherwise authorized by statute.

In addition to the FARs, the justification for leasing requires an analysis described in OMB Circular A-104 [2], entitled Evaluating Leases of Capital Assets. This circular specifies a fairly detailed procedure for making a decision to buy or lease. This procedure must be followed under any of the following conditions:

- The term of the lease, including option years, is five or more years.
- The term of the lease extends beyond 75 percent of the asset's useful life.
- The fair market value of the lease exceeds \$1 million.
- The asset is built expressly for the Federal government.
- The asset clearly has no alternative commercial use.
- OMB determines that an analysis is necessary.

The main message of the circular is that the least-expensive option must be chosen. However, if the available options consist of leasing now or buying later, a cost-benefit analysis to determine when to acquire the equipment must precede the lease/buy analysis. The circular devotes a great deal of space to outlining the methods for incorporating any special tax benefits conferred on the lessor through the agreement. This provision seems to be in response to the earlier discovery that leasing arrangements that appear to be less expensive to the military may be more expensive to the Government because of lost tax revenues.

Regulations Affecting Support

Under each of the alternative strategies, the Government can rely on the original contractor to provide minor modifications to the training device/system. In one program, the contractor receives authorization to make up to \$10,000 worth of hardware modifications and up to \$100,000 worth of software modifications. These modifications require no additional funding authorization but do require formal processing as an engineering change proposal (ECP). Major changes requiring more expensive software modifications require ASN approval and authorization of additional funds. The Navy reserves the right to submit these ECPs to competitive bidding.

To implement the option of bundling training devices and support, NTSC must obtain a waiver of the reliability and maintainability

requirements from the ASN, S&L. NTSC representatives reported that a previous request to exempt training devices from heat and vibration tests required a three-year battle.

Regulations Affecting Training Services

OMB Circular A-76 [3] establishes procedures to determine whether the Government contracts with a commercial firm for a good or service or relies on in-house facilities and personnel to provide it. This circular reflects the underlying philosophy that the Government should contract with commercial firms for goods and services whenever possible. The DCNO (Logistics) must review selected contractor and industrial activities once every five years to determine whether they are inherently governmental or can be provided by the private sector.

Department of Defense Instruction 4100.33 [4] offers additional guidance on the applicability of OMB circular A-76. This instruction lists circumstances when national defense or other considerations preclude the use of contractors. Generally, combat-unique and combat-related skill-training instruction programs do not satisfy the definition of a commercial- or industrial-type activity (CITA) and the Navy need not contract out that type of training. Directive 4100.15 [5] provides guidance for determining those other skill-training programs that are not considered CITA.

The Navy's ongoing concern with sea/shore rotation ratios places an additional constraint on contracting out. According to [6], "(o)ne of the principal limitations on contracting out a function is whether the billet assigned to the function is required for national defense (i.e., to maintain a rotation base for the career force)." The instruction states that contracting out initiatives that would drive the sea/shore rotation ratio for any rating beyond 3:3 will not normally be approved in the review of the Navy's Contracting Out Plan. In such cases, initiatives may be approved on an exception basis if they can be clearly shown to be in the Navy's best interest.

If the Navy does determine that training can be contracted out, OMB Circular A-104 requires a cost analysis that compares the cost of contracting out with the cost of an efficient in-house facility. The efficient in-house facility is not necessarily the same as the existing training facility. For example, the most efficient facility may employ civilian Government personnel rather than military personnel but retain the training facility within the Navy.

The Government typically uses an indefinite quantity contract to obtain training services. The FAR, Subpart 16.5, Indefinite Delivery Contracts, describes the use of this type of contract. In particular, Subpart 16.504 states that "An indefinite quantity contract should be used only for items or services that are commercial products...and when a recurring need is anticipated." The FAR, Subpart 16.504(a), requires

that the contract set both a maximum and minimum quantity in which the minimum quantity must be more than a nominal quantity in which, but not greater than the amount that the Government is fairly certain to order.

This overview of the regulations governing the procurement process suggests that, despite a general regulatory philosophy favoring the use of contractors whenever possible, the Navy must anticipate some institutional resistance to the widespread adoption of alternative acquisition strategies. Leasing appears to be subject to the most restrictive regulation, due to perceived abuses of the option in the past. Initiatives taken by NTSC, such as the bundling of training devices and support, quickly ran into a lengthy approval process. This may prove to be the rule rather than the exception as NTSC attempts to modify the current system by introducing some of the features of the alternative acquisition methods. While this effort is worthwhile, the Navy may be best able to achieve quicker procurements in the shorter term by adopting the training-services option, which appears to face the fewest regulatory constraints. There may be fewer constraints for this option, however because of the limited types of training contracted using this method. Attempts to use this option on a wider scale or extend it to combat training, particularly if this change affects sea/shore rotation ratios, may generate additional regulations.

EVALUATION OF ALTERNATIVES

Program managers at NTSC and contracting specialists at NTSC, the Washington Navy Regional Contracting Center (NRCC), and in the Air Force, as well as contractors in the training device industry, cited both potential advantages and difficulties with alternative acquisition strategies. Adoption of these alternatives does appear to create the potential for both time and cost savings. The implementation of these alternatives, however, will affect other aspects of training as well.

Time Lines

Time savings under the alternative acquisition strategies could occur in several ways. For example, all three of the alternatives require the contractor to be responsible for support of the equipment. This shift in responsibility should reduce many of the documentation requirements related to support of equipment, such as the ILS plan, since the same contractor both manufactures and supports the device. Reducing these requirements would result in significant time savings. In particular, much time could be saved if the contractor could avoid a variety of military specifications (MILSPECs). Implementing this change, however, would require approval from the ASN, S&L.

The contractor's incentive to complete a project varies with the timing of compensation. The Navy could increase the contractor's incentives to achieve RFT status by paying the contractor only after receiving operational equipment or at the completion of a training course. Partial or full payment during the development of the equipment or system weakens this incentive.

Adoption of the training-services option changes the type of product the Navy purchases and the specification of the requirement. In purchasing training devices, NTSC includes an engineering specification and related military standards in the RFP. Such detailed specifications allow the contractor little latitude in designing the equipment. It also tends to increase the complexity of the devices, making their design and manufacture more difficult and time consuming. In purchasing training services, the Navy instead must provide performance specifications identifying the skills to be taught. However, the contractor can exercise greater discretion in designing a training system, thus allowing its development to proceed more quickly.

Some Government personnel expressed skepticism about the long term potential for saving time by writing performance specifications. They cited difficulties in deviating from established procedure and questioned the desirability of eliminating engineering specifications. NTSC cited these standards as giving the Government the necessary element of control over the final product. They argued that without this type of specification, the contractor is far more likely to develop an unsatisfactory system. However, the realization of time savings under the alternative acquisition strategies follows from a performance specification and less detailed oversight of the system design. These features give the contractor greater flexibility, especially with respect to the technical side of the design process.

Performance Standards

The use of performance specifications should shorten the acquisition process both by allowing the contractor greater discretion during the development process and by reducing detailed Government oversight and related documentation requirements. However, several issues need to be addressed before such a policy can be adopted successfully.

Clearly, writing good performance specifications is essential to evaluating proposals and the contractor's performance. Carefully prepared performance specifications should reduce management later in the procurement process. The Navy must recognize, however, that current practice supports the use of engineering specifications. Government personnel qualified to write and evaluate engineering specifications are not necessarily the best qualified and experienced personnel to write and evaluate performance specifications. In addition, contractors recommended having senior people with experience in naval operations identify desired performance in the specifications and to make tradeoffs

between cost and performance. Once the specifications are written, the Navy must then give the contractor latitude to develop the training system with minimal oversight.

Evaluating performance specifications may be more difficult than evaluating engineering-type specifications. For example, if contractors determine the type of equipment best suited to teach various tasks, then the proposals may differ widely in terms of the mix of simulators, part-task trainers, and classroom training that make up the overall training system. Under the current system, the Navy determines the mix of training media in the development of the RFP. While this may limit the types of alternatives considered, it also limits the contractual complications resulting from proposal and contractor performance evaluation.

Some types of training may be less amenable to contracting by means of performance specifications because the desired product is not precisely defined. Tactical training, which emphasizes such intangibles as coordination and decision making, may be hard to measure. With team trainers, the problem becomes more difficult, because the contract cannot simply specify individual performance levels--the whole team must be evaluated. When the Navy does the training, this measurement problem also arises, but the complications associated with writing a contract for a product that is hard to define do not.

Carefully specified performance standards enable the Navy to evaluate proposals and the performance of the contractor after training begins. The Navy must anticipate that the contractor teaches "to the test," emphasizing those skills that determine whether or not the student passes the course. If the test does not reflect the desired skills, then the contractor may fulfill the terms of the contract without accomplishing the Navy's training goals.

COMMERCIAL APPLICABILITY AND CONTRACTOR RISK

Acquisition strategies that require a contractor to fund the development of a training system with reimbursement through leasing fees or per-student charges entail greater risk for contractors and discourage bidding on contracts. Two types of risk affect the decision to bid on a contract. The contractor faces the risk of being unable to satisfy the requirement at the fixed price listed in the contract. The contractor also faces the risk that Congress or the Navy will fail to fund the training.

The economic theory of agency, or the principal-agent problem, provides a framework for analyzing the optimal contract between the Government (the principal) and the contractor (the agent) in the presence of risk. In the standard principal-agent problem, the principal delegates some productive activity to the agent. The agent's effort in conjunction with unpredictable events determines the outcome.

The principal must determine the best way to compensate the agent. Two considerations enter this decision. First, the principal cannot directly observe the agent's level of effort, only the outcome, which depends on both effort and unpredictable events (the problem of moral hazard). Second, the greater the risk to the agent in undertaking the action, the greater must be the agent's reward. At one extreme, the principal can make the agent's compensation entirely dependent on the observed output, creating strong incentives but great risk for the agent. At the other extreme, the principal can guarantee the agent's compensation, making it independent of the outcome. This reduces the compensation required by the agent by eliminating uncertainty but also reduces the agent's incentive to perform.

Several extensions of the theory of agency address the particular problems found in Government procurement. The principal-agent framework has been applied to the problem of designing the optimal incentive contract. Under an incentive contract, the Government uses a linear payment schedule under which the contractor receives a fixed fee plus some proportion of project cost. Both a fixed-price contract and a cost-plus contract represent special cases of an incentive contract. The principal-agent framework has also been extended to a multiperiod situation. In this case, the principal can use the agent's past performance as an additional indicator of the agent's effort. Appendix B contains a detailed explanation of this theory. This theory provides a theoretical rationale for the tradeoffs between risk, incentives, and costs discussed in this study.

Under the leasing option, the contractor must invest in the development of training equipment. Contractors believe this aspect of leasing makes it the most risky option and have expressed great reluctance to enter into a leasing arrangement. The purchase-and-support option reduces the risk relative to the leasing option, because the Navy pays for the development of the training equipment. The contractor still faces the possibility that the Navy will choose not to renew the support contract during the option years. However, this "risk" creates the incentive for the contractor to perform. The risk under the training-services option depends on the particular contractual clauses used. The training-services option can be structured to separate procurement of specialized training equipment from ongoing services such as instruction and support. Examples of different types of training-services contracts discussed later reveal how different contractual features affect contractors' perceptions of risk.

COMMERCIAL APPLICABILITY AND COST

NTSC representatives and contractors agreed that the potential for cost savings under the alternative acquisition strategies exists only for training with commercial applications. A firm offering a training device or facility with both commercial and military applications can set prices that reduce the total cost to the Navy by spreading the fixed

costs of the investment over both types of clients. Without a commercial market and without a long-term commitment from the Navy, the contractor faces greater uncertainty about the return on the investment. Prices reflecting the greater risk may raise the life-cycle costs above the level associated with traditional procurements. Furthermore, risk indirectly raises costs by discouraging bidding.

Both economic theory and experience in contracting support the existence of a tradeoff between risk or uncertainty and cost. The Navy must consider the possible advantages of shifting risk to contractors against the higher cost. One possible advantage, highlighted in the principal-agent problem, is to create incentives for contractors to be responsive by linking payment with performance. However, contractors identify the main source of uncertainty as being the budget, i.e., funding. Contractors repeatedly voiced the concern that pressure on the budget will eliminate funding for training services, preventing the contractor from earning a return on the investment in the training facility. Because these funding cuts occur most often for reasons unrelated to contractor performance, the Navy gains little from shifting the risk created by uncertain funding on to the contractor.

Quantifying the tradeoff between risk and cost is very difficult. However, identifying factors that contribute to risk may help determine the best acquisition strategy for different procurements. Contractors' perceptions of the risk associated with investment in a training facility depend on (1) the commercial applicability of the training facility; (2) the nature of the requirement; and (3) the size of the investment relative to the size of the company providing the training. If funding seems assured, because the requirement is predictable, long term and noncontroversial, then the risk should be lower. Finally, some companies may be able to absorb risks with no special contract provisions. This is not an option for smaller firms for whom the termination of a contract could mean bankruptcy. Some well-known, established, training-services companies fall into this category.

While considerations of risk may dominate the cost of training under alternative acquisition strategies, these alternatives offer other sources of cost savings. Saving time often implies saving money. For example, contractors cited reduced documentation requirements relating to maintenance and support as a source of both time and cost savings. The fact that Navy personnel must also attend to professional development and other military duties indicates that private firms may be able to accomplish the same tasks with fewer workers, reducing the cost of training to the Navy.

Sole-Source Reprocurements

Several NTSC representatives voiced the concern that the alternative acquisition strategies lock the Navy into a sole-source position at the expiration of the contract. The Competition in Contracting Act of

1984 established full and open competition as the standard contracting method of procurement. As a result, the FAR requires special approvals before the contracting officer begins negotiations for a sole-source procurement. The contracting officer must justify the sole-source procurement by citing one of seven exceptions designated by Congress. Of these, NTSC currently cites the existence of only one responsible source or an unusual and compelling urgency in justifying about 90 percent of its requests for other than full and open competition [7].

In a sole-source environment, the contractor may adopt a "pay me now or pay me later" attitude, offering initially modest per-student fees and then raising them at the expiration of the original contract. The Navy then may encounter great difficulty finding a substitute. If the Government does not pursue a sole-source reprocurement, problems may arise. Other contractors may attempt to win the reprocurement with an unrealistically low bid. Because contracting officers find it easier to justify low bids, this strategy may work, leaving the Navy faced with poor-quality training. In summary, by leasing or contracting out training services, the Navy either ends up with too high a price (the original contractor gouges the Government) or too low a price (as contractors with inadequate facilities try to "buy in" to the contract).

If the potential payoff is large, the Navy can use some type of "flyoff" in which two contractors develop a prototype training system. The Air Force implemented this procedure in a limited way to procure a C-17 training facility. In the first stage of the solicitation, two contractors will design a training system. Then, the Government will select one of the contractors to develop the actual training system.

Another approach to this problem is the use of a fixed-price option to buy the training equipment and specialized facilities along with any documentation to operate the training facility as a part of the original contract. However, the decision to exercise the purchase option may require either a substantial lead time (to ensure the availability of the appropriate funds) or the reprogramming of funds.

The problem of sole-source reprocurements arises under all the acquisition strategies, including the traditional procurement process. NTSC awards production contracts to the firm awarded the prototype development contract about 80 percent of the time. The crucial concern is whether the alternative strategies make this problem greater by discouraging contractors from bidding on contracts and allowing the incumbent to charge prices above competitive levels. This may occur if the alternatives entail greater risk for the contractor. However, contractual methods that reduce risk to the contractor should reduce this problem.

Equipment Modifications

Training devices undergo frequent modification to reflect changes in operational equipment. Small changes in the operational equipment may mean major changes in the software driving a training device. Recent emphasis within the Navy on concurrency between training system development and operational equipment exacerbates this problem. The current system lacks any established procedure to ensure that equipment receives the necessary modifications. Indeed, one of the major advantages of the alternative acquisition strategies is that they specify a means of accomplishing engineering changes before changes are required.

No consensus emerged in this study on the best acquisition strategy to ensure timely modifications of equipment. Both the leasing and training-services options create strong incentives for firms to respond to changes in both technology and operational equipment. The contractor must stay current to be assured of contract renewal or, in the event of losing the lease, to find new clients.

The counterargument, in the case of the training-services option, focuses on the difficulty of establishing a fixed price per student given the frequency with which modifications occur. A contract based on a fixed fee per student does not seem amenable to constant modifications. However, pricing equipment modifications separately from instructional services addresses this concern. Several examples of the training-services option use this procedure.

Under current acquisition procedures, the development of a prototype trainer precedes the contract award for the production units. Typically, research and development (R&D) accounts in the Navy budget fund this effort using a cost-based contract. The prototype trainer can serve as a basis for establishing the fixed price per student. Because the Navy seldom requires training devices in large numbers, manufacturers do not expect to realize significant economies of scale, and the cost of the prototype should be a reliable predictor of production costs, after one allows for one-time R&D costs. A prototype establishes a benchmark against which other firms must compete, perhaps by developing an alternative prototype. Furthermore, the contract need not specify a fixed price per student if the program manager anticipates frequent modifications.

Instructor Quality Control

Contracting for training services may result in lower quality of instruction if instructors lack military experience with the operational equipment. However, training-services contracts typically include a clause giving the Navy some choice in selecting instructors. Contractors often hire recently retired Navy personnel to staff their projects. The Navy may decide to use some mix of civilian and military instructors, with Navy personnel acting as subject-matter experts and

advisors. Gradual implementation of contract instruction should ease the transition and alleviate some of the concerns. In addition, the Navy maintains some control through its ability to terminate the contract and suspend payment.

These considerations do not mean that the Navy maintains complete control over the quality of instruction. Instructors, whether retired Navy personnel or not, must keep current with Navy practice. The decision not to exercise an option to punish poor contractor performance inevitably disrupts the training process, and there may be close-out costs as well. However, the Navy maintains some checks on contractor performance and the quality of instruction.

Team Trainer Scheduling

Team trainers provide training for established teams within the fleets. Uncertainties about ship employment make it difficult to schedule these students, resulting in a training facility that sits idle during some periods and is used to capacity at other times. A leasing or training-services contract, as an indefinite-quantity contract, typically contains a clause that guarantees payment for a minimum number of students, whether or not those students appear. The Navy may pay for scheduled, not actual, training. If the Government buys a facility, the operators and maintenance workers upgrade and maintain the equipment during slack periods while instructors update the curriculum, analyze the results of tests, and attend to their own professional development.

This argument fails to establish a case against alternative acquisition strategies because the problem of idle equipment and instructors is the same whether the Navy buys equipment or leases equipment or purchases training services. When the Navy owns the equipment, the cost is implicit. The benefits accruing to the Navy from the equipment fall when the equipment is underutilized. When the Navy purchases training services or leases equipment, the cost is explicit. While explicit costs tend to be more noticeable than implicit ones, the loss of benefits because of scheduling difficulties is the same. The Navy may be able to reduce the potential dimensions of the problem by specifying a matrix of prices and enrollment levels stating the payment to be made to the contractor for different levels of attendance.

Budgetary Considerations

Use of the alternative acquisition strategies requires funding from different budget appropriations than under the traditional procurement process. Under the current system, the RDT&E appropriation provides the funds for the development of prototype equipment. The Five Year Defense Plan (FYDP) further categorizes these funds according to their use. NTSC uses 6.3 (Advanced Development) and 6.4 (Engineering Development) funds for most of their projects. Investment funds such as OPN (Other Procurement, Navy) provide the monies used to obtain production units.

The Military Personnel account provides funds for military instructors. The O&M,N account provides funds for ongoing services such as maintenance and support and civilian instruction.

The alternative acquisition strategies require a shift in funding from these accounts to Operation and Maintenance. In general, the O&M,N account receives less congressional scrutiny and oversight. However, many claimants compete for these funds, which may be the first to be cut under budgetary pressures. A major shift in funding for training from the traditional accounts to the O&M,N account could introduce an undesirable element of inflexibility into this account.

Manpower Requirements and Shore Billets

The alternative acquisition strategies generate substantial manpower savings by eliminating billets for operation, maintenance, and instruction. Given that manpower authorizations are less than requirements, the loss of such billets will not result in a loss of manpower and the Navy will be able to shift scarce billets to warfare areas. This factor apparently underlies the Navy's decision to eliminate simulator maintenance as an occupational specialty. However, this change also decreases shore billets, increasing sea-to-shore rotation ratios. In some occupations, a position as an instructor provides the only type of shore duty that allows an individual to use specialized skills. If these skills deteriorate rapidly with lack of use, then elimination of shore billets may adversely affect productivity. In addition, higher sea/shore rotation ratios have a well-known adverse effect on retention.

Navy policy on this point is clear. According to OPNAV Instruction 1000.16F, Chapter 6, Section 623, "(o)ne of the principal limitations on contracting out a function is whether the billet assigned to the function is required for national defense; i.e., to maintain a rotation base for the career force." The Instruction explicitly states that retention of needed shore billets takes precedence over contracting out.

The potential dimensions of this problem if the Navy adopts the training-services approach on a large scale are unknown. However, some considerations suggest that the impact may not be excessive. First, in adopting this approach, the Navy must train personnel to write performance specifications. Contractors constantly cite the need to use members of the fleet in developing the desired characteristics of the training system. The Navy can create new billets for subject-matter experts to be filled by fleet members assigned to shore duty. Second, the adoption of training services can be phased in gradually, to prevent any sudden, sharp decline in shore billets. Finally, with increasingly complex weapons systems, Navy personnel may need to spend more and more of their shore duty as students.

Conclusions

The training-services option appears to offer the greatest potential for time and cost savings. Savings would be realized because of the efficiencies gained when a single contractor is responsible for the complete training system and from a reduction in adherence to MILSPECS. However, the realization of time savings under this strategy depends in part on the ability of the Navy, as an institution, to adopt performance specifications that state requirements in terms of learning objectives for the student. This change may require development of new expertise and techniques for evaluating training. It also requires a change in the philosophy of acquisition that currently favors the use of engineering specifications for equipment to guarantee the satisfactory delivery of one component of a training system, the training device.

The realization of cost savings under the training-services option depends largely on the question of risk. In the case of contracting for training with purely military applications, the Navy must anticipate the concerns of contractors trying to recover the investment in a specialized training facility. In particular, funding uncertainties will inhibit competition in procurements, requiring the contractor to invest substantial amounts of money without a guaranteed return, even if the contractor performs in a satisfactory manner. Greater risks require greater rewards, which translates into higher prices for the Navy.

Other concerns about training services merit attention but do not eliminate the option as a viable method of acquisition. The Navy should avoid being "locked in" to a sole-source reprocurement by including "buy out" options in the original contract. Greater attention paid to projected enrollment and the goals of the training allows the Navy to tailor the contract to the specific training requirement, reducing contractual complications later in the process.

If the Navy decides to adopt the training-services approach on a large scale, then two other considerations may become very important, including the budgetary impact of this strategy and the effect on shore billets. The shift in funding for training under this option may create great uncertainties about the continuity of the training program. An adverse impact on sea/shore rotation ratios may generate opposition to the option.

EVIDENCE FROM NAVY AND AIR FORCE PROGRAMS

Studying examples of the alternative acquisition strategies reveals various drawbacks encountered in adopting nontraditional procurement processes. There are few, if any, examples, however, of leasing in the Navy training establishment to study. NTSC recently proposed using the purchase-and-support option in an acquisition, but no evidence on its effectiveness is available. Some examples of the training-services option drawn from the Navy and the Air Force illustrate the potential

cost and time savings to be achieved under this strategy. These examples provide some indication of the performance of contractors under this strategy as well as the difficulties in implementing this strategy. Several other related programs involving contract instruction provide some indication of the problems involved in scheduling and quality of instruction. Studying these various examples provides insight into the appropriateness of applying these strategies to different types of training systems.

Navy Ship-Handling Training

The Navy recently met the requirement for ship-handling training at the Surface Warfare Officers School (SWOS) by awarding a contract for training services to Marine Safety International (MSI). The contract commits MSI to construction of the building, purchase of training equipment, and development of coursework. Both MSI and its parent company, Flight Safety International, conduct their training business for commercial and military clients in this manner.

The Navy secured MSI's training services through a competitive procurement in which MSI made the low bid. The contract lasts for one year with four option years. Under the terms of the contract, MSI receives a flat fee per trainee. The Navy guarantees payment for a minimum of 790 students per year but may enroll as many as 1,200.

The time line specified in the original proposal, 18 months from the contract award to the RFT date, was met even though the facility includes additional features not found in the proposal. Construction of the training facility began in August of 1986 and was completed in July 1987. In January, training began with two simulators. MSI added two more simulators in July. According to Navy representatives at SWOS, the period from contract award to RFT typically lasts two to three years under NTSC procedures.

MSI representatives believe that private contractors can field training equipment more quickly because they use equipment that meets "acceptable commercial standards" rather than detailed military specifications. Construction of the building that houses the simulator required less time than a similar facility built by the Government because the contractors dealt only with one organization (the Navy) from start to finish.

The costs of training services under this arrangement fall significantly below the estimated costs of a Navy-owned and -operated facility over the five-year period. NTSC originally estimated the cost of the program over five years at \$15 million. MSI obtained the contract with a low bid of \$3.9 million over five years. However, additional features requested after contract award raised this figure to \$6.9 million. Even if one assumes that the original NTSC figures were inflated budget submissions and that MSI's original proposal was artificially low, the

magnitude of the disparity between the two figures suggests significant cost savings.

MSI representatives agreed that the ability to avoid documentation enters into their cost estimates for training services, noting that the cost of such documentation often exceeds the cost of the product in the case of software development. However, MSI also claimed that at current levels of utilization, the facility at SWOS is not a money-making operation. Their January press release suggests the Navy currently uses only 60 percent of the capacity of the facility.

The contract includes several provisions designed to protect the Navy against unsatisfactory performance by the contractor. The agreement allows the Navy to terminate the agreement after the first year if the training services prove unsatisfactory. The contract also includes an option granting the Navy the right to buy the equipment at the end of the four option years. This clause does not include an option to purchase the building housing the training. The MSI facility includes a generic full-bridge simulator that required a specially designed building. The Navy's specification for a vertical scene and current technology in the area of projection determined the building specifications.

Soon after the Navy awarded the contract to MSI, SWOS received a request from the fleet to develop an additional ship specification (aircraft carrier) and an additional harbor. MSI agreed to develop the necessary software for a one-time charge, which varies with the complexity of the ship/harbor. MSI retains copyright over the software even if the Navy exercises the purchase optional and buys the simulator.

Navy Air Crew Training

In the aviation area, NTSC manages two training-services programs. For about 20 years, NTSC has purchased training for the C-12, C-19, and C-131 aircraft from several companies, including FSI, Simu Flight, Frontier Airlines (prior to its bankruptcy), United Airlines, and American Airlines. This provides a counterexample to the claim that the Navy becomes locked in to a single contractor under this option. These aircraft do have commercial applicability, however, and so more competition for the training is expected. More recently, in August of 1986, NTSC secured training services for the E-6A TACOMO program. These planes, which are modified Boeing 707s, supply strategic communications with Trident submarines and cost about \$90 million. Because the Navy requires only a few of these planes, purchasing training planes did not appear to be cost effective.

The contractor provides a ground school, training aircraft, and uses simulators provided by the Government. The contractor teaches standard flying skills, and Navy personnel handle the sensitive military communications work. The Navy benefits from the TACOMO program because

the contractor handles the maintenance of the training equipment and the Navy need not commit scarce pilots to training billets.

Navy Reserve Training

Flight Safety International (FSI) provides training services to the Navy Reserve under two different contracts. In each case, the Navy specifies the courses to be developed. FSI complies with the contract by building a facility, obtaining training equipment, and operating and maintaining the facility. These programs have been ongoing since at least the early 1970s.

FSI provides services under an indefinite-quantity contract written for one year, with three option years. The contract is recompeteted during the last option year. In the past, only one or two contractors (including FSI) bid on the contract. This fact may indicate that other contractors see little opportunity to win a contract when a company is well established. However, a contract specialist familiar with these cases reports a growing interest in these contracts by other firms, particularly those with established operations providing similar services to the civilian community.

The total value of one of the current contracts is \$3 million, ranging from an annual value of \$.5 to \$.75 million. The annual guarantee is only \$10,000. FSI provides the instructors for these training programs. The Navy exerts control over the quality of the instructors only during the proposal-evaluation stage.

Navy Vocational Training

Congressional cuts in Navy manpower in the 1980 POM reduced by 526 the number of billets for the central Navy training organization, the Chief of Naval Education and Training (CNET). The Chief of Navy Technical Training (CNTECHTRA) responded by developing a program for contract instruction that currently employs 1,069 instructors at five different sites. The program's current appropriation is \$38 million per year. CNTECHTRA uses contract instruction primarily for A-school training but also for some C-school and P-school training.

The contract-instruction program differs from the training-services option in that the Navy provides the facilities and equipment. Discussions with CNTECHTRA representatives, however, provided useful information on the question of scheduling and quality of instruction. Originally, CNTECHTRA contracted with state institutions (which do not earn a profit), using sole-source procurements and cost contracts. Recent emphasis within the Navy on competition, however, means that CNTECHTRA now must seek competition for these contracts on a fixed-price basis. Student loading poses a problem with fixed-price contracts because the number of recruits surges during the summer months. This surge appears later in the A-schools and C-schools. On average, the

Navy training plan specifies 95 percent of actual throughput, but in FY 1984, the actual number fell way below the plan. Typically, in years with poor recruiting, actual attendance falls short of the anticipated level. Under a cost contract, the schools refund any money they save when the actual student count falls below the estimated number. Under an indefinite-quantity, fixed-price contract, the Navy must guarantee payment for a minimum number of students whether or not they appear.

Recently, CNTECHTRA chose a training program with a relatively stable student flow to serve as a pilot program for competitive procurements. CNTECHTRA found the resulting award to be successful, following some initial uncertainties. CNTECHTRA representatives believe that, with enough experience, scheduling should not pose insurmountable difficulties in contract training.

The question of quality control over instructors seemed to pose few problems. Many contractors hire retired Navy personnel to act as instructors, especially when training is conducted near the Navy bases where many retired Navy personnel live. In San Diego and Memphis, 95 percent of the instructors are former Navy personnel. This percentage falls to 60 percent at the Great Lakes facility, the lowest level at the five sites.

Air Force Flight Training

According to the Assistant Deputy Commander for Simulators, Aeronautical Systems Division, USAF, the Air Force recently initiated a new program for acquiring training systems, the Total Contract Training (TCT) system. The TCT program is based on the concept of complete reliance on contractors for development and operation of ground-based portions of training systems.

Manpower authorization constraints prompted the Air Force to adopt the TCT program. Like the Navy, the Air Force eliminated the simulator maintenance occupational specialty to move those manpower slots to operational billets. The Air Force also decided to move pilots acting as instructors to warfare positions. If pressure on manpower levels continues, the program is expected to expand despite some institutional resistance within the Air Force. The expectation of greater efficiency in terms of cost in the provision of aircrew training also influenced the decision to purchase training services.

The MAC program covers three kinds of cargo planes--the C-5, C-130, and C-17. While the Air Force had previously awarded a contract to train KC-10 tanker pilots to American Airlines Training Division, it formally initiated the TCT program by contracting with United Airlines for crew training for the C-5 aircraft. The Air Force awarded a second

TCT contract for the C-130 aircraft in April 1987. Source selection for a training program for the C-17 aircraft is underway. This program poses the greatest challenges to the contractor who must design the training system concurrently with the development of the aircraft.

The TCT program allows training devices to arrive in the field more quickly. In the Air Force, the procurement of training devices typically requires four years from RFP until the RFT date. (This figure refers only to obtaining equipment and does not include curriculum development since, prior to the inception of this program, the Air Force developed the curricula in-house.) In the case of the C-5 program, the Air Force issued the RFP on 6 November 1984, and the contractor held the first Course Readiness Review, a final stage in training system development, on 8 December 1986.

The potential for quicker and cheaper procurement arises because the Air Force adopted a strict hands-off policy, substantially reducing the number of interim reviews required and providing generally less oversight. The Government issues an RFP with the desired performance standards to be met at the end of the contract. The contractor determines how to meet those requirements. In the case of aircrew training, the Air Force issues an RFP specifying the type of training need, the expected level of throughput, and the "output" of the training. The MAC programs require that students pass a check ride with an Air Force evaluator or return to the course at contractor expense. Air Force representatives consulted about this project unanimously agreed to the importance of reducing Government oversight of the program to speed the development of the training system.

The RFP includes limited military standards (MIL-STDs), minimizing them whenever possible, and directs the use of the best commercial practices in their absence. The FAA certifies that the simulators replicate the aerodynamics of the particular aircraft. The FAA performs this function for all commercial aircraft simulators. The key to the elimination of MIL-STDs in nonaviation training (for which there is no counterpart to the FAA) is to specify the equipment as nondevelopmental items (NDI) or a modified NDI.

The TCT plan addresses the question of contractor risk, in part, by separating procurement of the training device from the provision of training services. Because the Air Force provides funding for training device development, the Government owns the equipment. In most cases, the Government takes title when the contracting officer's technical representative signs the DD Form 250, typically when the training device is shipped to the site. In other cases, the Air Force delays taking title, providing title to any training devices to the contractor who assumes responsibility for its operation and support during the life of the contract.

In specific cases, the Air Force furnishes the equipment to the contractor. In the case of the C-5 program, the Military Airlift Command provided United Airlines with some devices and spares. The simulators, however, were obsolete and required extensive overhauls. In addition, United Airlines built several new training devices. In the case of the C-130 program, the Air Force possessed relatively new simulators that were recently fitted with new visual systems. The Air Force provided these to the contractor who assumed responsibility for the operation of an existing training facility.

The option years extend 14 years beyond the original 1-year contract. The Air Force applied to the DAR Council for a blanket waiver to the contract length requirements for all training contracts. The Council refused to issue the waiver and referred the matter back to the Air Force commands, suggesting that the commands issue waivers on an individual project basis.

Each year before exercising the yearly option, the contracting officer must "test the market." After two to three years, the system achieves a fairly stable configuration, and another contractor may be able to offer training at a price below the option price. In addition, the list of contractual delivery items includes a complete data package that would allow another contractor to assume operation and support of the training system. The option years and data package provide some protection to the Air Force against becoming locked in to a single contractor.

Modifications to the system need not require renegotiation of the contract. The Air Force distinguishes between minor and major modifications. The minor modifications meet predetermined definitions expressed in lines of code for the software and dollar figures for hardware. After a Training Systems Readiness Review, program management shifts to the Air Force Logistics Command (AFLC). Minor modifications require approval only from the using command. AFLC must approve major modifications for which competition might be sought. The contract requires the prime contractor to cooperate fully in this situation. Modifications that affect curricula require approval from the using command.

The contract addresses the problem of uncertain student enrollment by specifying figures in a potential throughput matrix. This matrix lists price/throughput combinations to which the firm agrees at contract award. Payments then vary with student loadings according to this matrix without any additional contract modifications.

The Air Force maintains control over the quality of the training in several ways. During the development stage, Air Force representatives attend the Engineering Design Review and the Critical Design Review. Subject-matter experts work on site to advise the contractors regarding whether the curriculum satisfies the requirements. These subject-matter

experts have no authority over the contractors but may report their perceptions of the curriculum to their Air Force superiors. In addition, some contracts specify experience levels for the instructors.

Contracting officers for the Air Force characterized the C-5 contract as one lacking the usual adversarial relationship between the contractor and Government. The project progressed smoothly with few changes. Several unanticipated problems arose during the development of the training system, however, that required close attention. Students appeared without the specified experience. This amounted to a change in the ground rules upon which contractor performance was based. There were delays in obtaining GFE, especially instrumentation. Finally, the Air Force needed to expand the potential throughput matrix to include enrollment levels below the anticipated level.

Historical Perspective

On a somewhat whimsical note, it is worth commenting that contracts have not always been voluminous. Undoubtedly, the current world is very complex. Agreements, however, were not always precisely defined. Good will and common sense on the part of all parties to a contract were assumed to be present and sufficient to resolve most problems. An example of such a Government contract from the beginning of this century is included in appendix C. It is small, has an imprecise specification, and would probably be orders of magnitude larger if issued today. However, the contract succeeded and history was made.

Conclusions

The Navy's ship-handling training contract and the Air Force TCT program approximate the type of contract envisioned under the training-services option. These examples of the training-services option illustrate the potential cost and time savings to be achieved under this alternative acquisition strategy. These examples do differ in several important respects, however, including contractor risk and modifying equipment.

Contractors indicated that they much prefer the Air Force program because of the reduction in risk to the contractor achieved by separating the procurement of devices from the purchase of ongoing services, such as maintenance and instruction. There seem to be no benefits to shifting this risk entirely on to the contractor. The contractor still faces the possibility that the Navy will choose not to exercise the options in the contract. The option years thus provide an incentive for the contractor to perform to the Navy's satisfaction.

The Navy did not fully anticipate the need to incorporate provisions for modifying equipment in contracting for the ship-handling trainer. In that case, the generic nature of the simulator makes modifications relatively straightforward, allowing the Navy to contract

for the additions by making a one-time, relatively modest payment per additional ship type or operating environment. Modifications of other types of training devices may be considerably more complex and expensive. The Air Force TCT program anticipated the need for modifications engendered by changes in operational equipment and included provisions relating to modifications in the original contract. Table 3 highlights key differences in comparing the Navy ship-handling and Air Force C-5 training contracts.

TABLE 3
COMPARISON OF SHIP-HANDLING AND C-5 CONTRACTS

	<u>Navy ship-handling</u>	<u>Air Force C-5 program</u>
Ownership of equipment	Contractor	Government
Pricing	Fixed fee per student	Separate procurement of trainer
Number of option years	4	14

CONCLUSIONS AND APPLICATION TO CURRENT TRAINER PROGRAMS

The training-services approach offers the most promising alternative to the traditional procurement process for Navy training systems. This approach to training is well established in the commercial sector and there are contractors willing and able to supply this type of service. Existing regulations do require some cost studies before adopting this approach. The regulations do not discourage the approach, however. The benefits of the leasing and bundling of training devices and support options are more uncertain, in part because there are few examples of this approach in either the private or the public sector. Contractors expressed great reluctance to lease equipment because leasing shifts the risk of developing training equipment on to the contractor, with little apparent benefit to the Government.

This study did not identify any factors that rule out the use of the training-services option for any type of training. The Navy must anticipate opposition to this strategy, however, because of tradition (especially with regard to combat training), regulatory impasses (i.e., uncertainty about the authority to deviate from established procurement procedures), and the potential impact on sea/shore rotation ratios. These problems may arise only if the Navy adopts the strategy on a widespread basis.

The differences between the ship-handling training and other training required by the Navy limits the usefulness of the contract as a model for procuring other types of training. In fact, no single contract is likely to provide an adequate model for purchasing all types of training services, because the problems in the implementation of this strategy vary with the type of training.

The evaluation of alternative acquisition strategies and the examples drawn from the Navy and Air Force offer guidance in determining the best procurement method to use in meeting various training requirements. A representative list of training devices for the surface Navy includes operator trainers, maintenance trainers, and team trainers. Specific examples of these types of training devices include:

- Device 14E35/35C, AN/SQQ-89 operator trainer
- Device 14G1/G1C, AN/SQQ-89 basic sonar operator/basic diagnostics trainer
- Device 14G2 , AN/SQQ-89 common equipment maintenance trainer
- Device _OF16, command tactical trainer
- Device 14A12, surface tactical team trainer
- Device 19F series, surface fire fighter trainers.

The operator and maintenance training devices provide training on the AN/SQQ-89 multisensor system. The other training devices provide generic training. The surface tactical trainer and the surface fire-fighter trainers are both team trainers.

The main considerations in purchasing training services for different types of training are (1) contractor risk, (2) type of skills to be taught, and (3) the anticipated need for equipment modification. High-risk investments may limit the number of contractors bidding on a contract and raise the cost of the training system. The types of skills to be taught affect the difficulty of writing performance specifications for the training services. These specifications must be clear, to evaluate proposals and to assess the performance of the contractor. The anticipated need for equipment modification determines the types of contract clauses necessary to ensure that training corresponds to operational practice.

Contractors' perceptions of the risk associated with investment in a training facility risk depend on (1) the commercial applicability of the training facility, (2) the nature of the requirement, and (3) the size of the investment relative to the size of the company providing the training. The main source of uncertainty in making the investment is

the budget process. Contractors repeatedly voiced the concern that pressure on the budget will eliminate funding for training services, preventing the contractor from earning a return on the investment in the training facility. If funding seems assured, because the requirement is predictable and long term and not clouded by political controversy, then the risk should be lower. Finally, some companies may be able to absorb risks with no special contract provisions. This is not an option for firms for whom the termination of a contract could mean bankruptcy. Some well-known, established training-services companies fall into this category.

Ship-handling training, which currently serves as the prototype for training services in the Navy, differs from other trainers in several areas that affect risk. MSI invested \$6 million to \$10 million in the development of the training facility. The complex can be used to teach ship-handling skills to commercial clients with relatively modest changes in hardware and software. Contractors foresee a long-term requirement for this type of training, with few changes in the types of skills taught and little disagreement over the need for the training. These factors reduce the risk to the contractor in investing in the training facility.

In contrast, the other training devices have few direct applications in the commercial sector. While states and municipalities conduct training in fire fighting, the Navy's facility emphasizes fighting fires on ships. The commercial or nonmilitary market for this type of training may be very thin. The tactical trainers must be tailored specifically for the U.S. Navy. The SQQ-89 trainers apply to a specific type of sensor system. The projected funding for these projects indicates that these training facilities require a greater investment than the ship-handling facility. If investing in a training facility is riskier, the Navy must anticipate both fewer bidders and higher costs.

The advantages to the Government of shifting the risk of investment to the contractor are not clear. The Air Force TCT program offers another approach to contract training that eliminates much of this risk without eliminating all incentives for the contractor to perform as well. The Air Force program clearly merits some consideration as an alternative to the ship-handling trainer. The TCT program does benefit from the existence of an outside agency, the FAA, with established commercial standards. Determining acceptable commercial practice without such an agency may well be difficult.

The type of training varies along two relevant dimensions: (1) team training or individual training and (2) anticipated changes in the training skills. Evaluating a team is far more difficult than evaluating an individual, and so writing a performance specification stating the skills to be learned through the training program will be more difficult for team training than for individual training. The process becomes more complicated if the nature of the training is

expected to change frequently. For stable generic training such as ship-handling, writing performance specifications poses no great difficulty. Writing a performance specification for a tactical team trainer may be much harder.

All training devices require modification. For weapon-system-specific training, changes in the operational equipment mean changes in the training equipment, ranging from cosmetic changes in the appearance of the equipment to extensive hardware and software modifications. If the weapon system has achieved a stable configuration, the contract may need relatively simple clauses relating to modifications. With the emphasis on achieving concurrency with the new introduction of weapon systems, however, adding simple clauses may prove to be the exception, not the rule. The type and frequency of modifications anticipated must be considered in writing the training-services contract.

The differences between ship-handling training and the other types of training found in the surface Navy indicate that using some but not all of the contractual features found in the ship-handling contract may be desirable. More specifically, the following conclusions were drawn from the study:

- The training-services option provides the most promising alternative to the current procurement process for training, particularly with respect to the time necessary to develop the training facility.
- In the examples of training services found in the Navy and the Air Force, the potential for time savings arises from reliance on commercial standards and performance specifications that free the contractor from excessive oversight in developing the training system. In addition, the involvement of a single organization leads to faster development.
- Contractual features to reduce the risks involved in the investment in a training system may be advisable and necessary in the case of training unique to the military if the Navy wants to interest many different contractors.
- Specification of performance standards requires great care to avoid contractual problems in evaluating proposals and in evaluating contractor performance. This will change the nature of the front-end analysis performed by the Navy and may require a different type of expertise.

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APPENDIX A
THE NTSC ACQUISITION PROCESS

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THE NTSC ACQUISITION PROCESS

This appendix describes the acquisition process followed by the Navy Training Systems Center (NTSC). NTSC organizes a project team to oversee the acquisition process. A project manager heads the team and assumes overall responsibility for the procurement. The team also includes personnel responsible for front-end analysis, budgeting documentation, design studies, support, and other aspects of the procurement process.

The NTSC acquisition process consists of four components:

- Analysis
- Development
- Support
- Funding.

The funding component (as well as the other components) was briefly described in the main text. Funding for training resembles funding for any other budgeting activity within the Navy, and therefore, is not discussed further in this appendix. The analysis, development, and support components have many characteristics that are unique to the NTSC acquisition process. These characteristics are described more fully.

ANALYSIS

The analysis component begins with the identification of both a training deficiency and possible solutions to remedy the deficiency. The sponsor must choose a particular training solution. The project team then defines the physical and functional requirements of that training system.

The analysis component proceeds in three stages, listed below, each resulting in a set of key documents.

Front-End Analysis

- Training Situation Analysis: This document highlights deficiencies in the present training system and requires from four months to two years to complete.
- Problem Analysis: This document defines a specific training deficiency.

Alternative Selection

- Plan of Action and Milestones (POA&M): This document defines the path to be taken to accomplish the procurement. Upon sponsor approval, the project manager issues internal tasking assignments.
- Development Options Paper: This paper describes the possible solutions available for correcting a training deficiency.

Training System Design

- Military Characteristics (MC): The military characteristics document results from a training situation analysis of the knowledge and skills required to operate and maintain a weapon system or item of tactical equipment. The development of the MC requires from three to four months to three to four years. This document establishes the agreement between the sponsor, the FPT, and NTSC and requires formal CNO approval. Additional steps beyond this stage require budgetary authorization.

DEVELOPMENT

During the development component, NTSC awards the contract and oversees the performance of the contractor. The process proceeds in the following four stages.

Contract Definition

During this stage, the project team assembles the acquisition package and develops the request for proposal (RFP). The acquisition package contains all of the data necessary to go to contract. It defines the Government's requirement and certifies both the funding for the project and the authorization to spend those funds. The RFP solicits bids on the contract. The RFP contains separate sections describing various contractual requirements. These sections include:

- Device specification
- Contract data requirements list (CDRLs)
- Technical proposal requirement (TPR).

The project manager must also develop an acquisition plan, describing the contracting activities proposed for the project, and a proposal evaluation plan, describing the methods to be used for evaluating contractor proposals. Both the acquisition plan and the proposal-evaluation plan must be submitted for approval by the Assistant

Secretary of the Navy for Shipbuilding and Logistics (ASN, S&L). Routine approval requires three to nine months.

Source Selection

During this stage, the project team must evaluate proposals and award the contract. Key events falling in this phase include:

- Bidders' conference for clarification of questions
- Receipt of technical proposals
- Receipt of cost proposals
- Completion of technical evaluation
- Completion of proposal evaluation report
- Contract award.

These tasks routinely require 15 months. The size of the proposals affects the length of the evaluation period. For example, a 2,000-page proposal requires six weeks to read. In addition, the RFP must be synchronized with the budgetary process to ensure that funding authorization coincides with contract award.

Contract Negotiation

During this stage, the contract specialist must negotiate with the contractor selected during source selection. Key events include:

- Defense Contract Administration/Defense Contract Audit Agency (DCAS/DCAA) Audit: An audit of the contractor's proposal requested by NTSC and conducted by the DCAS/DCAA.
- Pre-Negotiation Memorandum: This document describes the Government's negotiation position based on the technical evaluation by NTSC and DCAS/DCAA and requires ASN, S&L approval, which takes two to three months. However, a sole-source justification requires three months to one year for approval.
- Post-Negotiation Memorandum: This document describes the results of negotiations between NTSC and the contractor.

Contractor Design and Development

During this phase, the project manager oversees the work of the contractor to ensure compliance with the terms of the contract. The contractor must supply detailed integrated logistics support (ILS) data

at the conclusion of this stage. Key events falling in this phase include:

- Post-Award Orientation Conference: At this conference, NTSC personnel orient the contractor to administrative procedures, expected performance, and reporting requirements.
- Preliminary Device Configuration Report Review: In this report, the contractor presents the proposed device layout configuration and operation.
- Mock-Up Review Conference: NTSC and FPT members review the mock-up and proposed operations of the device at the contractor's plant.
- Contractor Preliminary Inspection: The contractor performs complete functional tests of the device in accordance with approved Trainer Test Procedures and Results Reports (TTPRR), witnessed by DCAS.
- Government Preliminary Inspection: The Government verifies that the device meets contractual requirements prior to shipment to the training site.
- Contractor Final Inspection (On-Site): The contractor tests the device in accordance with the TTPRR after installing the device at the training site.
- Government Final Inspection: The Government tests the training device at the site.
- Government Acceptance: The program engineer, as the contracting officer's technical representative (COTR), with the concurrence of the FPT, signs DD Form 250, certifying the satisfactory installation and testing of the training device.
- System Ready for Training: The training system (including the device, curriculum, and support elements) meets the requirements of the MC. Upon FPT approval, the user assumes control of the training system.

SUPPORT

The support component begins with the shift from development to production, deployment, and support of the training system. This transition requires that consideration be given to the problems of supporting the training system early in its development.

During the analysis phase, the ILS manager assembles a team to establish, update, and evaluate the ILS portions of the project. Preparation of an ILS plan begins immediately after project initiation with a draft ILS plan.

At the end of development, the contractor must supply the following critical support items:

- Interim Support Items List: This document lists the spare parts recommended by a device manufacturer to be procured by the Government for use during the interim period from acceptance of the device until the establishment of normal supply channels.
- Maintenance Tools and Support Equipment List: This document lists the tools and test equipment recommended during the interim period.
- Technical Data Support Package: This document lists all data necessary to enable the support personnel to meet the operational and maintenance concept.
- Logistic Support Analysis: An analysis generated by a device contractor that forms the basis for determining the logistic support of a device.

The original equipment manufacturer provides logistic support during the initial support period. Then the successful bidder under the Contractor Operation and Maintenance of Simulators (COMS) program assumes responsibility for support of the training device.

APPENDIX B

THE PRINCIPAL-AGENT PROBLEM AND GOVERNMENT PROCUREMENT POLICY

APPENDIX B

THE PRINCIPAL-AGENT PROBLEM AND GOVERNMENT PROCUREMENT POLICY

INTRODUCTION

This appendix provides a general introduction to the principal-agent literature in economics. This literature provides the theoretical rationale for the assertions made about the relationships between risk, incentives to perform, and bidding found in the main text.

The principal-agent problem falls within a branch of economics concerned with situations in which economic agents have access to different information. In the principal-agent problem, the principal delegates some action to an agent. The outcome depends on both the effort of the agent and a random state of nature. The principal only observes the state of nature and the outcome; the agent's effort is unobservable. Economists refer to situations in which the outcome of a transaction depends on information known to only one party as the problem of moral hazard.

In the classic example of a principal-agent problem, a landlord hires a tenant to farm his property. The crop depends on both the tenant's efforts and the weather. The uncertainty associated with the weather means that the landlord cannot unambiguously infer the agent's effort from the level of output. This means that in developing a compensation scheme, the landlord must consider the agent's incentives to work.

One way to motivate the tenant is to make his compensation depend at least partially on the level of output. This shifts some of the risk from uncertain weather from the principal to the agent. The optimal level of effort for the agent depends on the degree to which the principal shares the risk. The optimal contract from the principal's point of view must balance the need to motivate the agent to work against the desire to share some of the risks.

Several extensions of the principal-agent problem clarify some of the tradeoffs between risk and incentives to perform in the design of Government-procurement contracts. Weitzman [B-1] examines the problem of designing an optimal incentive contract. Both a fixed-price contract and a cost-plus contract are special cases of an incentive contract. McAfee and McMillan [B-2] introduce bidding into the principal-agent framework. They show how incentives to perform must be balanced against both risk-sharing considerations and the willingness of contractors to bid on contracts. Lambert [B-3] extends the analysis in a different direction, examining the principal-agent problem when contracts last for several years.

THE STANDARD PRINCIPAL-AGENT PROBLEM

The standard principal-agent problem addresses the question of designing the optimal contract in the presence of both uncertainty (which makes risk sharing between principal and agent desirable) and moral hazard (which requires the principal to consider the work incentives of the contract). Early formulations of this problem used a first-order approach in which the principal chooses the optimal risk-sharing contract or incentive scheme subject to two constraints. The first constraint requires the agent to receive some minimum level of utility. This constraint reflects the assumption of an outside market for the agent's services. The second constraint requires the agent to be at a stationary point with respect to choice of action.

Subsequent research described in Rogerson [B-4] and Milgrom [B-5] demonstrated the limitations of this approach. In particular, the second constraint requires only that the agent choose an action at which his utility is at a stationary point. A more general approach must instead require the agent to take utility-maximizing actions. By ignoring second-order conditions, this approach cannot provide generally valid qualitative conclusions about the Pareto optimal or efficient contract. Additional research, however, has identified classes of situations in which the first-order approach is valid. The extensions of the standard model considered here fall into these categories and make use of the first-order approach.

In the formal model, the principal is risk neutral or risk averse with utility function over income $u(y)$ where u is strictly increasing, concave, and twice continuously differentiable. The agent is strictly risk averse with a separable utility function defined over income and actions given by $v(y)-a$, where a is effort and v is strictly increasing, strictly concave, and twice continuously differentiable.

The agent chooses an action or level of effort from the set a . This action, given the state of nature, produces an outcome, x , measured in terms of a cash-flow to the principal. The set of possible outcomes x is assumed to be finite where $x = \{x_1, \dots, x_n\}$. The probability of outcome j occurring, given action a is $p_j(a)$. This probability is assumed to be positive for all possible values of a and j and twice continuously differentiable.

The contract, s , between the principal and agent specifies the payment to be paid to the agent conditional upon the observed outcome x . The utility functions $U(s,a)$ and $V(s,a)$ denote the expected utility of the principal and agent given the contract s and action a chosen by the agent, where

$$U(s,a) = \sum_{j=1}^n p_j(a) u(x_j - s_j)$$

and

$$V(s, a) = \sum_{j=1}^n P_j(a) v(s_j) - a .$$

A contract is efficient if no contract exists that gives the principal higher expected utility and gives the agent at least V_0 , where V_0 is the guaranteed minimum expected utility level of the agent. With these assumptions and definitions, the efficient contract emerges as the solution to the following maximization problem:

$$\begin{array}{l} \text{Max } U(s, a) \\ s, a \end{array}$$

subject to

$$V(s, a) \geq V_0 ,$$

and

$$V(s, a) \geq V(s, \bar{a}) \text{ for every } \bar{a} \in A .$$

The first-order approach substitutes the simpler requirement that the action taken by the agent define a stationary point for this requirement (i.e., $\partial V / \partial a = 0$ at the particular values of a and s).

INCENTIVE CONTRACTS

Defense procurements typically specify some variation of an incentive contract. Weitzman [B-1] applies the principal-agent framework to the problem of designing the optimal incentive contract. Under an incentive contract, the Government uses a linear payment schedule under which the contractor receives a fixed fee plus some proportion of project cost. The principal's payment, P , equals a fraction λ of realized costs, c , and a fixed fee, d , and is expressed as

$$P = \lambda c + d ,$$

where $(1 - \lambda)$ is the agent's share of project costs. Weitzman explores the efficient incentive contract by characterizing the optimal sharing ratio λ .

Under a fixed-price contract, the contractor agrees to a fixed-dollar price, which, once negotiated, will not be readjusted to reflect actual cost experience. Every dollar saved creates a dollar of profit, and the contractor's incentives to reduce project costs are strong. Because the firm also bears the risk of higher costs, the Government must compensate the contractor with a fee that includes a higher profit. Under a cost-plus-fixed-fee contract, the Government pays the contractor a fixed fee based on a percentage of estimated cost and also

agrees to reimburse the contractor for any cost overruns. The risks to the contractor of unexpected cost increases are low, as are the incentives to keep costs down. In general, an incentive contract falls between these two extremes and offers the possibility of striking a balance between the positive incentive effect of a high sharing ratio and the negative risk effect.

The agent or contractor must determine the best response to the incentive contract faced with uncertainties about realized costs. The contractor's net profit, π , is described by

$$\pi = P - c(\theta) + \pi_0 ,$$

where $c(\theta)$ denotes realized costs, θ denotes the state of nature, and π_0 denotes profits from other activities of the contractor. The availability of π_0 gives the contractor the discretion to reduce project costs at the expense of profits from other activities. The agent chooses its discretionary effort after uncertainty about realized costs resolves itself. The maximum level of other profits $M_\theta(c)$ depends on the state of nature θ and realized costs $c(\theta)$. The firm's best response to the contract maximizes $M_\theta(c) - (1 - \lambda)c$ with respect to c (and implicitly with respect to action). This implies $M'_\theta(c) = (1 - \lambda)$.

If λ is less than 1, the contractor must cover some portion of unexpected project cost increases and earn a fraction of any cost underruns. The higher is λ , the lower is the agent's incentive to reduce project cost at the expense of other profit.

The principal or Government must choose λ and d to maximize $U(y)$, subject to the constraints that the agent receive some minimum level of expected utility V_0 and that the agent is at a stationary point. More formally, the efficient incentive contract (λ^*, d^*) satisfies the constraints

$$\text{Max}_{\lambda, d} U(-d - \lambda c_\theta(\lambda))$$

subject to

$$V(d - (1 - \lambda) c_\theta(\lambda) + M_\theta(\lambda)) \geq V_0 \quad (\text{B-1})$$

and

$$M'_\theta = (1 - \lambda) . \quad (\text{B-2})$$

Equation (B-2) determines $c(\lambda)$ and $M(\lambda)$. The optimal d emerges as the solution to (B-1), given $c(\lambda)$ and $M(\lambda)$. Expressing c , d , and M as functions of λ allows the optimization problem to be reduced to

$$\max_{\lambda} \{U(-d(\lambda) - \lambda c_{\theta}(\lambda))\} .$$

The first-order condition for the simplified problem yields the optimal sharing ratio, λ^* , where:

$$\lambda^* = \epsilon / (\epsilon - 1 + \bar{c}_V / \bar{c}_U) .$$

In this formulation, ϵ measures the responsiveness of project costs to changes in the sharing ratio, and \bar{c}_i , $i = U$ or V , is the weighted average project cost with weights equal to the product of expected marginal utility of income in each state and the probability of occurrence of that state.

Using this expression for the optimal sharing ratio, Weitzman demonstrates several propositions about the optimal incentive contract. Increases in the principal's risk aversion result in a larger share to be paid by the agent. Increases in the agent's risk aversion result in a smaller optimal share to be paid by the agent. If the principal is risk neutral and the agent risk averse, so that \bar{c}_V / \bar{c}_U exceeds 1, a ceteris paribus situation with lower cost variance reduces \bar{c}_V / \bar{c}_U . This means a less risky distribution of c_{θ} is associated with a smaller value of λ and a larger agent share.

This theory implies that the optimal sharing ratio depends on such features as uncertainty of costs, risk aversion of the agent, and the contractor's ability to control costs. Not surprisingly, when the contractor enjoys greater discretion over project costs, as measured by ϵ , he should be made to bear a greater share of those costs. If the contractor can do little to cut costs, the theory suggests that the firm be freed of the burden of the risk, in which case it can be paid a lower fixed fee. This implication relates to the assertion made by the contractors that the source of the risk lies not in cost uncertainties but in funding uncertainties over which they exert no control. Contractors are willing to accept fixed-price contracts (accepting the risk of cost uncertainties) but prefer up-front payment for the investment in the training facility.

McAfee and McMillan [B-2] also examine optimal incentive contracts. They extend the analysis by including a model of bidding. The standard principal-agent problem addresses the tradeoff between incentives to perform and risk sharing. The bidding model introduces a new effect that reinforces the risk-sharing effect. In this situation, the agent must determine both the profit-maximizing choice of effort (to reduce costs) and the equilibrium choice of bid, given the form of the contract. The principal must choose the sharing ratio to minimize expected payments while taking into account each agent's response in

terms of both bidding and effort. In determining the optimal sharing ratio, the principal must recognize that higher ratios encourage increased effort by the agent to reduce costs. At the same time, higher sharing ratios decrease bidding competition and risk sharing.

The model defines the incentive contract in terms of the agent's bid, b , and realized costs, c . Letting P continue to represent the principal's payment,

$$P = b + \lambda(c - b) .$$

This formulation defines a cost-plus contract when $\lambda = 1$ and a fixed-price contract when $\lambda = 0$. The fixed fee becomes irrelevant in this model because competition between bidders implies lower bids for higher fixed fees.

The realized costs for firm i , c_i , has three components:

$$c_i = c_i^* + \theta - h(a) ,$$

where c_i^* equals expected opportunity costs including any risk premium, θ is a random variable representing unexpected costs, and $h(a)$ represents the dollar cost of actions to reduce project costs.

The optimal sharing ratio solves a constrained optimization problem in which the risk-neutral principal minimizes the expected payment under the contract, given the potential bidders' optimizing responses. The risk-averse agent selects the expected-utility maximizing choice of bid, b , and cost reduction, a , given the sharing ratio. The agent's choices can be treated separately by considering first the expected utility-maximizing choice of effort if awarded the contract and second, the choice of bid under a symmetric Nash equilibrium.

The condition characterizing the expected-payment-minimizing choice of λ requires the principal to set the marginal benefit of increases in λ equal to the marginal cost of increases in λ . The marginal cost to the principal of increasing λ results from the moral hazard effect. Increases in λ result in higher expected payments due to a reduction in effort by the agent to lower costs. These variations in costs with respect to variation in λ may be expressed as

$$\partial(h(a) - a)/\partial\lambda ,$$

or the marginal return to the agent's cost-reducing activities due to a change in λ , which the firm captures.

The marginal benefit to the principal of increasing λ results from two separable effects of changes in λ on the agent's actions. As λ

increases, expected payments to the agent decrease through a risk sharing effect and a bidding-competition effect. Together these effects equal the effect of changes in λ on the agent's expected profits or:

$$\partial(E(\pi_i))/\partial\lambda \quad .$$

At the optimum, one obtains

$$\partial(h(a) - a)/\partial\lambda = \partial(E(\pi_i))/\partial\lambda \quad .$$

The bidding effect operates even if the agents do not require a premium for uncertainty. This analysis provides a theoretical basis for the assertions by contractors that the uncertainty associated with the use of option years creates an incentive to perform that must be weighed against the possibility of higher costs and fewer bidders.

One implication of this model is that a cost-plus contract is never optimal. Whenever $\lambda < 1$, the agent must bear a fraction of any increases in contract costs beyond the level established by the bid. As a result, firms with higher expected costs must submit higher bids. In contrast, under a cost-plus contract, a high-cost firm has no incentive to bid more than a low-cost firm.

In addition, the fixed-price contract is optimal only in the special case in which the number of bidders becomes very large and they are risk neutral. These results add support to the recent emphasis on fixed-price contracts but suggest that the use of incentive contracts is preferable, particularly with a view toward increasing competition and bidding for contracts.

MULTIYEAR CONTRACTS

The previous models implicitly assume a one-period horizon. The use of option years in a contract introduces the possibility of using the outcome in one period to assess the agent's unobservable effort. Indeed, in the extreme case in which the principal-agent relationship lasts for an infinite number of periods, the principal can completely eliminate the incentive problem. A simple model in which production is separable across time and states of nature are independent over time demonstrates this point.

With these assumptions, if the agent chooses the level of effort that is optimal from the principal's point of view, that is, the first-best level of effort, then variations in output depend solely on variations in the state of nature. Because states of nature are independently distributed over time, output is independently and identically distributed over time. Furthermore, as the number of periods increases, the variance of average output declines. The principal can detect shirking by comparing average output to the level of output to be expected if the agent exerts the first-best level of effort. With an

infinite horizon, the uncertainty is diversified away, eliminating the incentive problem.

Lambert [B-3] examines a two-period principal-agent problem that he generalizes to any finite horizon. In a finite-horizon model, the principal cannot completely eliminate the incentive problem. In particular, if the agent enjoys good luck in the first period, and second-period compensation depends on the outcome in the first period, the agent may exert less effort in the second period.

However, Lambert shows that the optimal second-period sharing rule depends on the first-period outcome. In this model, the principal chooses the contract, s , at the beginning of period one to maximize expected utility over the two-period horizon. Again, two constraints limit the choice of contract. First, the agent must receive some minimum level of expected utility over the two-period horizon. Second, the agent's strategy must be a best response to the principal's contract.

The principal selects a contract, s_t , specifying the compensation of the agent in each period. The compensation scheme can depend on any jointly observable variables. In particular, second-period compensation can depend on first-period performance, measured as a cash-flow x_t . This cash-flow is assumed to be known at the beginning of the second period. The principal's strategy can be represented as

$$SP = \{s_1(x_1), s_2(x_1, x_2)\} .$$

The agent selects an action, a_t , which together with the state of nature θ determines x_t . The agent's effort in period two may depend on past performance, so that the strategy may be represented as

$$SA = \{a_1, a_2(x_1)\} .$$

The utility functions $U(y)$ and $W(y)$ represent the preferences of the principal and agent over income. These functions are assumed to satisfy typical continuity and concavity conditions. In addition, these functions are additively separable by period. Income received in period one is available for consumption only in that period. The agent's utility is a decreasing function of effort, so that $V(y, a) = W(y) - c(a)$.

When both the principal and the agent precommit to a long-term contract, the principal's problem becomes

$$\begin{array}{l} \text{Max } U(s, a) \\ (s, a) \end{array}$$

subject to

$$V(s, a) \geq V_0$$

and

$$V(s, \bar{a}) \geq V(s, a) \text{ for every } \bar{a} \in A.$$

The assumption of separability in both production and utility means that there is no reason to make the solution to the principal-agent problem, (s_t, a_t) , depend on past performance in the absence of the incentive compatibility constraint. In this simplified model, the presence of moral hazard alone requires the agent's compensation to depend on past performance. Furthermore, with the incentive compatibility constraint, the structure of the contract provides the only link between the agent's action in period two and performance in period one.

Using a dynamic programming approach to determine the agent's strategy and simplifying by assuming that the agent's choice of effort in each period can be represented by his first-order condition on effort allows the constraints characterizing the agent's behavior to be written as

$$E W_2(s_2(x_1, x_2)) \partial \{p_2(x_2 | a_2(x_1))\} / \partial a_2 - \partial \{c_2(a_2(x_1))\} / \partial a_2 = 0,$$

and

$$E \{W_1(s_1(x_1)) + E(V_2(s_2(x_1, x_2), a_2(x_1)))\} \\ \partial \{p_1(x_1 | a_1)\} / \partial a_1 - \partial \{c_1(a_1)\} / \partial a_1 = 0.$$

The agent selects second-period effort so that its effect on expected marginal utility of income is equal to the marginal disutility of effort. The agent selects first-period effort in the same way but must also consider the effect that a_1 has on second-period effort and second-period income.

The principal maximizes expected utility subject to these constraints. The principal's maximization problem may be rewritten as a Lagrangian problem with multipliers for the effort constraints and the expected utility constraint. Lambert demonstrates several propositions relating to the signs of the Lagrange multipliers. First, the agent's second-period compensation is an increasing function of second-period cash-flow. Second, given a positive multiplier for the first-period

effort constraint, the second-period sharing rule depends on the first-period outcome. The principal uses both current-period and future-period incentives to motivate the agent's effort in each period. The second-period incentives reinforce the first-period incentives in encouraging the agent's effort during the first period by making both first-period compensation and expected second-period utility depend on the first-period outcome.

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- [B-3] Richard A Lambert. "Long-term Contracts and Moral Hazard." *Bell Journal of Economics*. 14 (Autumn 1983): 441-452
- [B-4] William P. Rogerson. "The First-Order Approach to Principal-Agent Problems." *Econometrica* 53 (1985): .1357-1369
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APPENDIX C

A CONTRACT FOR ONE HEAVIER-THAN-AIR FLYING MACHINE

Signal Corps, United States Army.

These Articles of Agreement entered into this-----tenth----- day of
February---, nineteen hundred and eight---, between----Chas. S. Wallace----,
Captain-----, Signal Corps, United States Army, of the first part, and

Wilbur and Orville Wright, trading as Wright Brothers, of
1127 West Third Street, Dayton,

in the county of-----Montgomery-----, State of-----Ohio----- of
the second part, WHEREAS, that in conformity with copy of the advertisement, specifications, and
proposed accounts attached, and which, in so far as they relate to this contract, form a part of it, the
said-----Chas. S. Wallace, Captain,-----
Signal Corps, United States Army, for and in behalf of the United States of America, and the said
-----Wright Brothers-----
(hereinafter designated as the contractor) do covenant and agree, to and with each other, as follows, viz:

Article I. That the said contractor shall manufacture for and deliver to
the United States of America,

One (1) heavier-than-air flying machine, in accordance with
Signal Corps Specification No. 486, dated December 28, 1907.

Art. II. That the deliveries of the supplies and materials herein contracted for shall be made in
the manner, numbers, or quantities, and for each number or quantity, on or before the date specified
therefor, as follows, viz:

That complete delivery shall be made on or before August
28, 1908.

Art. III. All supplies and materials furnished and work done under this contract shall, before
being accepted, be subject to a rigid inspection by an inspector appointed on the part of the Government,

and such as do not conform to the specifications set forth in this contract shall be rejected. The decision of the Chief Signal Officer, United States Army, as to quality and quantity shall be final.

ART. IV. That for and in consideration of the faithful performance of the stipulations of this contract, the contractor shall be paid at the office of -----the Chief Signal Officer-----
-----of the ARMY-----, at-----Washington, D. C.--- for all supplies and materials delivered in conformity with the requirements of this contract, on or before the dates above specified (Article II, *supra*) and accepted, the following prices, viz:

One (1) heavier-than-air flying machine at a total cost of twenty-five thousand (\$25,000) dollars.

to be paid as soon as practicable after the acceptance of the same, in funds furnished by the United States for the purpose, reserving per cent from each payment until final settlement, on completion of the contract or otherwise.

ART. V. It is further agreed that for all supplies and materials which shall not be delivered in conformity with the requirements of this contract on or before the dates prescribed therefor in Article II. above, but which shall be subsequently delivered and accepted, the prices shall be as follows:

1-1122

Arr. VI. That in case of the failure of the said contractor to perform the stipulations of this contract within the time and in the manner specified above, Articles I to III, inclusive, the said party of the first part may, instead of waiting further for deliveries under the provisions of the preceding article, supply the deficiency by purchase in open market or otherwise, at such place as may be selected (the articles so procured to be the kind herein specified, as near as practicable); and the said contractor shall be charged with the increased cost of the supplies and materials so purchased over what they would have cost if delivered by the contractor on the date they were received under such open-market purchase.

Arr. VII. It is further agreed by and between the parties hereto that until final inspection and acceptance of, and payment for, all of the supplies and materials and work herein provided for, no prior inspection, payment, or act is to be construed as a waiver of the right of the party of the first part to reject any defective articles or supplies or to require the fulfillment of any of the terms of the contract.

Arr. VIII. The contractor further agrees to hold and save the United States harmless from and against all and every demand, or demands, of any nature or kind for, or on account of, the use of any patented invention, article, or process included in the materials hereby agreed to be furnished and work to be done under this contract.

Arr. IX. Neither this contract nor any interest herein shall be transferred to any other party or parties, and in case of such transfer the United States may refuse to carry out this contract either with the transferor or the transferee, but all rights of action for any breach of this contract by said contractor are reserved to the United States.

Arr. X. No Member of or Delegate to Congress, nor any person belonging to, or employed in, the military service of the United States, is or shall be admitted to any share or part of this contract, or to any benefit which may arise therefrom.*

Arr. XI. That it is expressly agreed and understood that this contract shall be noneffective until an appropriation adequate to its fulfillment is made by Congress and is available.

Arr. XII. That this contract shall be subject to approval of the Chief Signal Officer, United States Army.

IN WITNESS WHEREOF the parties aforesaid have hereunto placed their hands the date first hereinbefore written.

WITNESSES:

<u>John J. Mullaney</u>	as to	<u>[Signature]</u> Chief Signal Officer, U. S. Army.
<u>Albert Lawrence</u>	as to	
<u>W. E. Taylor</u>	as to	
<u>H. H. Hoffman</u>	as to	
		<u>Wright Brothers</u> by <u>Orville Wright</u>

APPROVED: FEB 28 1908, 190

[Signature]
Brigadier General,
Chief Signal Officer of the Army.

*Here add to any contract made with an incorporated company for its general benefit the following words, viz: "But this stipulation, so far as it relates to Members or Delegates to Congress, is not to be construed to extend to this contract." See section 8740, Revised Statutes.

(RECORDED IN QUOTIFLATS.)

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SIGNAL CORPS SPECIFICATION, NO. 486.

RECEIVED
JAN 20 1908
SIGNAL CORPS DIV.

ADVERTISEMENT AND SPECIFICATION FOR A HEAVIER-THAN-AIR FLYING MACHINE.

TO THE PUBLIC:

Sealed proposals, in duplicate, will be received at this office until 12 o'clock noon on February 1, 1908, on behalf of the Board of Ordnance and Fortification for furnishing the Signal Corps with a heavier-than-air flying machine. All proposals received will be turned over to the Board of Ordnance and Fortification at its first meeting after February 1 for its official action.

Persons wishing to submit proposals under this specification can obtain the necessary forms and envelopes by application to the Chief Signal Officer, United States Army, War Department, Washington, D. C. The United States reserves the right to reject any and all proposals.

Unless the bidders are also the manufacturers of the flying machine they must state the name and place of the maker.

Preliminary.—This specification covers the construction of a flying machine supported entirely by the dynamic reaction of the atmosphere and having no gas bag.

Acceptance.—The flying machine will be accepted only after a successful trial flight, during which it will comply with all requirements of this specification. No payments on account will be made until after the trial flight and acceptance.

Inspection.—The Government reserves the right to inspect any and all processes of manufacture.

GENERAL REQUIREMENTS.

The general dimensions of the flying machine will be determined by the manufacturer, subject to the following conditions:

1. Bidders must submit with their proposals the following:

- (a) Drawings to scale showing the general dimensions and shape of the flying machine which they propose to build under this specification.
- (b) Statement of the speed for which it is designed.
- (c) Statement of the total surface area of the supporting planes.
- (d) Statement of the total weight.
- (e) Description of the engine which will be used for motive power.
- (f) The material of which the frame, planes, and propellers will be constructed. Plans received will not be shown to other bidders.

3. It is desirable that the flying machine should be designed so that it may be quickly and easily assembled and taken apart and packed for transportation in army wagons. It should be capable of being assembled and put in operating condition in about one hour.

3. The flying machine must be designed to carry two persons having a combined weight of about 350 pounds, also sufficient fuel for a flight of 125 miles.

4. The flying machine should be designed to have a speed of at least forty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight, according to the following scale:

- 40 miles per hour, 100 per cent.
- 39 miles per hour, 90 per cent.
- 38 miles per hour, 80 per cent.
- 37 miles per hour, 70 per cent.
- 36 miles per hour, 60 per cent.
- Less than 36 miles per hour rejected.
- 41 miles per hour, 110 per cent.
- 42 miles per hour, 120 per cent.
- 43 miles per hour, 130 per cent.
- 44 miles per hour, 140 per cent.

5. The speed accomplished during the trial flight will be determined by taking an average of the time over a measured course of more than five miles, against and with the wind. The time will be taken by a flying start, passing the starting point at full speed at both ends of the course. This test subject to such additional details as the Chief Signal Officer of the Army may prescribe at the time.

6. Before acceptance a trial endurance flight will be required of at least one hour during which time the flying machine must remain continuously in the air without landing. It shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight. During this trial flight of one hour it must be steered in all directions without difficulty and at all times under perfect control and equilibrium.

7. Three trials will be allowed for speed as provided for in paragraphs 4 and 5. Three trials for endurance as provided for in paragraph 6, and both tests must be completed within a period of thirty days from the date of delivery. The expense of the tests to be borne by the manufacturer. The place of delivery to the Government and trial flights will be at Fort Myer, Virginia.

8. It should be so designed as to ascend in any country which may be encountered in field service. The starting device must be simple and transportable. It should also land in a field without requiring a specially prepared spot and without damaging its structure.

9. It should be provided with some device to permit of a safe descent in case of an accident to the propelling machinery.

10. It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time.

11. Bidders must furnish evidence that the Government of the United States has the lawful right to use all patented devices or appliances which may be a part of the flying machine, and that the manufacturers of the flying machine are authorized to convey the same to the Government. This refers to the unrestricted right to use the flying machine sold to the Government, but does not contemplate the exclusive purchase of patent rights for duplicating the flying machine.

12. Bidders will be required to furnish with their proposal a certified check amounting to ten per cent of the price stated for the 40-mile speed. Upon making the award for this flying machine these certified checks will be returned to the bidders, and the successful bidder will be required to furnish a bond, according to Army Regulations, of the amount equal to the price stated for the 40-mile speed.

13. The price quoted in proposals must be understood to include the instruction of two men in the handling and operation of this flying machine. No extra charge for this service will be allowed.

14. Bidders must state the time which will be required for delivery after receipt of order.

JAMES ALLEN,

Brigadier General, Chief Signal Officer of the Army.

SIGNAL OFFICE,
WASHINGTON, D. C., December 29, 1907.

END

DATE

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